Department of Defense
Legacy Resource Management Program

PROJECT 13-382

Design Guidelines for Implementing Energy Efficiency Strategies in Historic Properties Phase II

CHERRY/SEE/REAMES ARCHITECTS

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The following people volunteered to read the 50% draft of Phase 1 of this report (21 of the Guidelines) and to offer comments. They provided a tremendous help to the report team. While not all of the comments could be incorporated, all suggested improvements assisted in some aspect of the final document. We believe their time and diligent effort has made this report far more useful than we could have made it without their input. We are extremely grateful for their assistance.

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DEVELOPMENT OF THIS DOCUMENT:

This document, which was funded in full by the Department of Defense Legacy Resource Management Program, was developed in two phases. The first phase was completed in 2012, under DoD Project Number 11-382. The second phase was completed in 2014, under DoD Project Number 13 382. Phase 1 included 21 Guidelines, and Phase 2 included 19 Guidelines. For ease of use, both phases have been merged together into this single document. For the purposes of this merged document, DoD Project Number 13-382 was used throughout.

PURPOSE OF THESE GUIDELINES:

The purpose of these Guidelines is to facilitate the planning of rehabilitation projects that will result in improved energy efficiency in historic buildings operated by the Department of Defense (DoD).

USING THE GUIDELINES:

Guideline users should familiarize themselves with Part I, Introduction, and the titles and scope of the Guidelines contained in the document. As potential projects are identified, review Part II, Guidelines 00 01, 00 02, and 00 03 and applicable Guidelines with the intention of applying them to a specific project. The Guidelines are arranged in keeping with building industry categories as described in Part I. The format of the document is arranged so that more Guidelines can be added in the future.

The Guidelines assume that the reader does not have a background in energy conservation, engineering, or building design or construction. Abbreviations and a Glossary are included to assist with the understanding of the vocabulary and concepts of energy conservation in historic buildings (see Appendices O and P). Most Guidelines make reference to sources on the Internet that can expand one's knowledge and increase energy conservation awareness and options.

COST/BENEFIT ANALYSES:

The major issue for energy conservation improvements is often the Cost/Benefit Analysis or Return on Investment (ROI). Section 3, in Part I. Introduction, "The realities of Cost/Benefit Analyses", explains the issues involved in determining the cost and benefits of various improvements prior to their execution. They must be specific to place, climate, use, and the historic character of the facility. Wherever appropriate, a Guideline will provide a method for making an approximation of cost and benefit in terms of energy savings. However, it is important to realize that no such approach can guarantee a result because of the numerous factors beyond the control of the person doing the calculation. There is no way to predict future weather, staff behavior, fuel prices, etc. The calculation processes suggested should offer a good guide to selecting among various options for improvement, and that information can be very helpful.

HISTORIC PRESERVATION GUIDANCE:

Historically, buildings were designed to conserve energy because energy was scarce and expensive. Use of these Guidelines can help preserve our history, make historic buildings useful, and once again conserve energy.

1. PURPOSE OF THESE GUIDELINES:

The purpose of these Guidelines is to facilitate the planning of rehabilitation projects that will result in improved energy efficiency in historic buildings operated by the DoD. The Guidelines are intended to be used by DoD CRMs, Facility Managers and design teams to help these groups meet Historic Preservation and Energy Saving design goals for projects and the development of Requests for Proposal for design services by architects and engineers. They are not intended to be a technical analysis. The Guidelines have a secondary purpose of assisting DoD staff who manage historic buildings in meeting the legal obligations that all federal agencies have in the preservation of our national heritage, as detailed in the National Historic Preservation Act of 1966. The DoD is legally required to meet energy efficiency conditions due to Federal Executive Order (EO) 13514. All DoD construction projects regardless of scope and size must also meet the Unified Facilities Criteria (UFC). These Guidelines are meant to be used in conjunction with the UFC for permanent construction and provide potential options for meeting the established Criteria. In many cases, the Guidelines exceed the criteria set forth in the UFC, but in no case should they replace the UFC.

2. HOW TO USE THESE GUIDELINES:

How are the Guidelines Arranged?:

The landscape orientation of the Guidelines serves several purposes. First, landscape more closely matches computer monitor configurations, making it easier to read the document on the computer screen instead of printing the entire document. Not printing the document will save paper and energy, and thus is the more efficient option. This orientation also allows for a large graphic column adjacent to the text which facilitates greater use of graphics.

The Guidelines are loosely arranged according to the Construction Specifications Institute (CSI) Master Format. CSI is an organization founded in 1948 by the construction specification writers of government agencies to improve the quality of construction specifications, develop best practices, and establish standards and formats for those specifications. The CSI Master Format for construction specifications is widely used as a standard format for the construction industry. Additionally, this format allows Guidelines to be added throughout the document at a later time in the appropriate location, which would be difficult with a sequential format.

PAGE LAYOUT

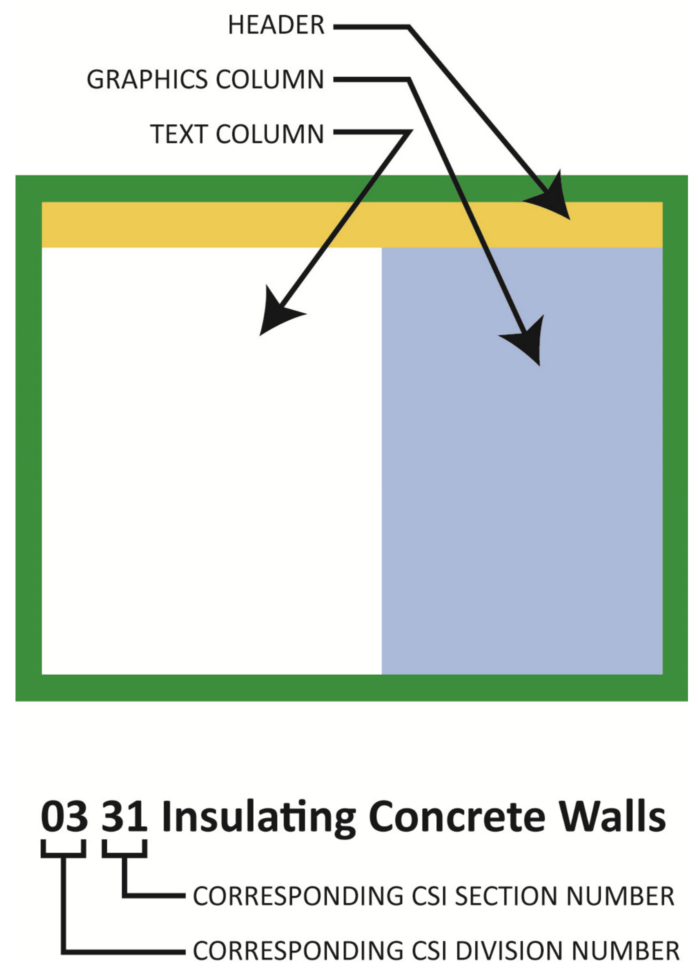


Figure P1-1

2. HOW TO USE THESE GUIDELINES continued:

How are the Guidelines Arranged? continued:

The first two numbers of the Guidelines match the corresponding CSI Division number. The second two numbers match the corresponding CSI Section numbers where possible. Since the Guidelines are relatively few in number in comparison to the CSI Master Format, the Guidelines are only four digits long instead of the CSI six-digit format.

There will be a cross-reference notice at the beginning of each Guideline to facilitate the use of items that overlap. For example, the placing of rigid insulation on the inside of a masonry wall will specifically be covered in Guideline 04 21 Insulating Masonry Walls, but important general insulation information will be covered in Guideline 07 21 Thermal Insulation. However, it is assumed that all readers will read the Introduction, and Guidelines 00 01, 00 02 and 00 03 before getting into more specific issues.

It is assumed that this document will be used like a dictionary, with the reader selecting only those sections relevant to the situation at hand. For this reason, some information is repeated in several Guidelines so that each guideline can stand alone.

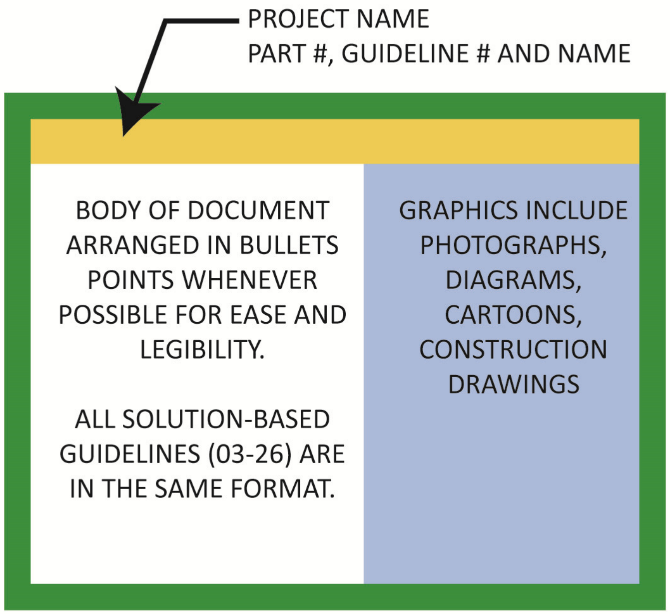


Figure P1-2

Format of Guidelines:

Guideline numbers and titles are listed in the Table of Contents, and on each Guideline's header and footer. Each Guideline generally follows the outline below:

- **Guideline Description:** A brief description of the content addressed in that Guideline
- **Related Guidelines**: lists the Guideline numbers and titles
- **General Notes**: related to all aspects of the Guideline are listed
- **Considerations**: for a particular type of work or product related to the Guideline. There may be several Considerations per Guideline, each having all the steps described below.
- **Approach**: a brief description of how the work is done or how the product is installed
- **Applicable Secretary of the Interior Standards:** for Rehabilitation, abbreviated "SOI Standards" throughout the document
- **Historic Preservation Effects:** A brief description of the issues that might be encountered
- **Energy Saving Potential:** In general points and formulas, where appropriate
- **Cost Considerations:** Always relative to the circumstances since cost is very specific to the building, location, etc.

2. HOW TO USE THESE GUIDELINES continued:

Format of Guidelines continued:

- **Other Considerations**: and additional information, if appropriate

The Guidelines that are more general in content do not strictly follow the above outline. Guidelines 00 01, 00 02 and 00 03 address project organization and management rather than specific improvements to be made on a historic building. Other Guidelines, such as 07 21, also break from the above outline as needed.

Starting a Project Using These Guidelines:
Review the list of Guidelines in the Table of Contents to know the topics available here. Then, first read the three Guidelines at the beginning: 00 01, 00 02, and 00 03. These Guidelines will help one organize their project tasks relative to the historic preservation and energy issues. Of course, any building rehabilitation project involves much more than these two topics, but issues of funding, consultant selection, scheduling and the host of other concerns are well beyond the scope of this report.

Keep in mind that these Guidelines are to be used in conjunction with all other applicable codes and standards including but not limited to the DoD Unified Facilities Criteria (UFC)(latest edition), the International Building Code (IBC), and the National Fire Protection Association (NFPA). The design team should always consult all applicable codes and standards during the actual design process. These Guidelines may be used to help meet or exceed the code requirements.

Remember that while this document is intended for an audience with a wide range of skills from technical to historians, it is not a technical analysis. The intention is for those with a technical background to learn the historic preservation language and concerns, and those with preservation backgrounds to learn the technical language and concerns. It does not replace the expertise of a qualified design professional who is focused on a specific project with all of the nuances associated with that project.

Common Abbreviations used in this Guideline:
See Appendix P for a complete list.

AHU *– Air Handling Unit*

ASHRAE – *American Society of Heating, Refrigeration, and Air-Conditioning Engineers*

HVAC *– Heating, Ventilation, Air-Conditioning*

LEED – *Leadership in Energy and Environmental Design*

MAU – *Makeup Air Unit*

RTU *– Roof Top Unit*

SMACNA *– Sheet Metal and Air Conditioning Contractors National Association*

DX *– Direct Expansion (Refrigeration Cycle)*

VRF *– Variable Refrigerant Flow*

EER *– Energy Efficiency Ratio*

SHPO *– State Historic Preservation Officer*

SOI *– Secretary of the Interior*

3. THE REALITIES OF COST / BENEFIT ANALYSES:

Every building owner wants to know the Return on Investment (ROI) for improvements. Owners always want to know the answers BEFORE the project begins. The realities are that the answers can only be known after the project has been occupied for a few years.

The reasons that predictions on installation costs compared to benefits (Return on Investment or ROI) cannot be accurately estimated include countless unpredictable variables. These are:

- "What will the weather be like for the years being measured?"
- "How much will energy costs go up in the life-time of this improvement?"
- "Exactly what equipment/materials will be specified and provided?"
- "How many times will the staff and visitors open windows and doors?"
- "How many times will the staff and visitors remember to turn off the lights when leaving?"
- "How many times will the staff and visitors adjust the thermostats; etc?"
- As well as other unpredictable aspects of human behavior that impact energy use.

In addition, the circumstances of each historic building are very different. A great deal of energy is transferred through windows, perimeter walls, roofs, and floors. Because the total area of windows, walls, roofs and floors varies in every building, there are no simple approaches which can determine eventual cost benefits compared to initial cost for each project.

While the big picture of cost/benefit comparison is very difficult to predict, more can be known in advance about individual improvements in terms of energy saving potential. There are many online calculators that can be used to these ends and that take into account the efficiencies of the different equipment. Please refer to the Interactive Excel Tables on pages 9 and 10 for a sample calculation that can also be used. These calculations, customized to the building in question, can predict a cost savings resulting from energy savings for a single improvement. That amount can be compared to the cost of purchase and installation of that improvement. In other words, a reasonable cost benefit may be predicted regarding individual improvements. It is not possible to test this prediction after construction and occupancy because the specific savings on that improvement will not be discernible from the energy bills nor do many military installations have individual meters.

Figure P1-3

An example of a 1940's DOD office, Pentagon Building History Exhibit, July 12, 2012. DOD photo by U.S. Army Sgt. 1st Class Tyrone C. Marshall Jr.

Unlike the two dimensional cutouts in the Pentagon display, building users are not static. How they use a facility is constantly changing. This reality makes figuring out a cost/benefit analysis highly specific to a particular building and location.

3. THE REALITIES OF COST / BENEFIT ANALYSES continued:

In Part II, sections beginning with 23 involve Heating, Ventilation, and Air Conditioning (HVAC) systems. Because these systems must be custom designed to the specific situation of a building, these Guidelines cannot provide a potential square foot cost. These sections recommend a life cycle analysis or assessment (LCA) prepared by a professional. An LCA, as defined by the United States Environmental Protection Agency (EPA), is "a technique to assess the environmental aspects and potential impacts associated with a product, process, or service." (Life Cycle Analysis Definition, 2012) For a more in-depth discussion on LCAs read EPA document EPA/600/R-06/060 "Life Cycle Assessment: Principles and Practice," which can be found on the EPA website (www.epa.gov).

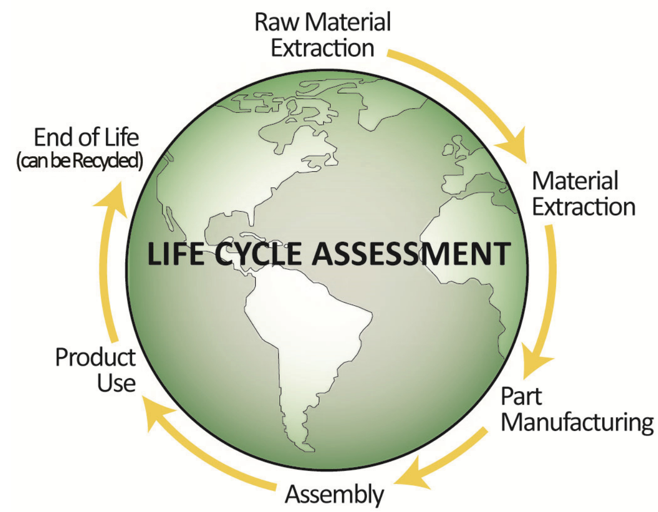


Figure P1-4

It is also important to remember that cost alone is not the only consideration. There are numerous advantages to increasing the thermal comfort of a building and reducing energy use that cannot be readily quantified. These benefits include increased productivity of staff with improved HVAC systems, reduction of dependence on foreign sources of imported energy, and reduction of CO2 in the atmosphere. Benefits of reusing historic buildings can include greater productivity due to the use of natural light, a more interesting work environment depending upon the design of the historic building, and often a higher quality of material finishes and details than can be afforded in contemporary buildings.

Keep in mind, buildings built in the 1970's used the most energy (Btu/ft2) of any time period from pre 1920's through 2010.

- Buildings from the 1960's are starting to become eligible for historic status.
- Even though these buildings might not be the most efficient, it is still important to preserve them as part of our history.

3. THE REALITIES OF COST / BENEFIT ANALYSES continued:

Energy Savings Potential and Cost Considerations as presented in the Guidelines:

Many of the Guidelines in this document discuss Energy Savings Potential and Cost Considerations as presented below. It is recommended that either the online calculators or the Interactive Excel Tables on page 10 be used for the actual calculations. In some of the Guidelines, however, the energy and cost information is less easily quantifiable using this type of calculation. In these cases, a more general discussion of Energy Savings Potential and Cost Considerations, which does not include calculations, has been provided.

Key Concepts Defined:

- **Heating and Cooling Degree Days:** Different areas of the country require different amounts of heating and cooling to achieve comfort in buildings.
  - **Heating Degree Days** (HDD) refers to the demand for heating in that area.
    - For HDD, a value would be the number of days multiplied by the average temperature difference between the outside temperature and a desired average indoor temperature, typically 65 degrees (averaging desired day and night temps).
    - For example, Albuquerque, NM has 919 HDD in January (averaged from 2007 to 2011). This information means that in January with 31 days, there was an average (919/31) of 29.6 degrees (called Delta T) that had to be made up with energy for heating. This calculation can also be done on an annual basis.
  - **Cooling Degree Days** (CDD) refers to the demand for cooling in that area.
    - For the same years, Albuquerque had 424 CDD in July, meaning that in 31 days there was an average DeltaT of 13.67 degrees (424/31days) to be reduced by cooling.
  - To determine the HDD and CDD for one's area see http://www.degreedays.net/.
  - Similar information may be obtained by contacting one's local weather bureau.
- **R –values**: R-values are used to represent the insulation value of materials.
  - **Insulation** is the resistance of heat (energy) transfer and higher insulation (higher R-values) reduce the heating or cooling requirements of spaces.
  - R-values generally have the units (hour x sf x degF)/BTU for a given material.
    - Sometimes defined on a per-unit-thickness basis, with the units hour x sf x degF/(BTU x in). BTU is British Thermal Unit, see Appendix O for the Glossary.

Common Abbreviations Used in Calculations:

x	*multiply*
/	*divide*
sf	*square feet*
degF	*degrees Fahrenheit*
in	*inches*
kWh	*kilowatt hours*
hr	*hour*
HDD	*heating degree days*
CDD	*cooling degree days*
COP	*coefficient of performance*
EER	*energy efficiency ratio*
Insul	*insulation*
bd	*board, as in gypsum bd*
BTU	*British Thermal Unit, see definition in Glossary, Appendix O*

3. THE REALITIES OF COST / BENEFIT ANALYSES continued:

Key Concepts Defined continued:

- **R –values continued**:
    - If the R-value is defined per inch of thickness then the actual material thickness needs to be known. For example, if a rigid insulation is R-5 per inch, and the material is 2" thick, the total R-value will be R-10.
- **U –factors**: U-factors are the inverse of R-values and measure how well heat is conducted through the assembly.
    - Materials with lower u-factors reduce heating and cooling losses. For example, high-performance windows can be u-0.3 (equivalent to R-3.33) while lower performing windows can be u-0.6 (equivalent to R-1.67).
- **COP:** The **coefficient of performance** is the ratio of heating or cooling provided (watts) divided by the electrical energy consumed (watts).
    - Better performing equipment has a higher COP. COP is unit-less because it is a ratio of watts/watts.
    - COP is listed on manufacturer's specifications.
- **EER:** The **energy efficiency ratio** is similar to COP and is the ratio of output cooling (BTU/hr) to electrical energy input (watts).
    - EER is equal to COP multiplied by 3.412 because there are 3,412 BTU in one kWh.
- **Gas Heating Efficiency:** Gas heating equipment is commonly measured in a percentage of heat output versus gas energy input. It is also listed on manufacturer's specifications.
    - Indoor gas heating equipment can be up to 98% efficient while outdoor equipment is normally only 80% efficient.
- **Using the Tables and Online Calculators:** Online calculators are available to help estimate the energy and cost savings that could be realized if better insulation were installed in an existing building (one example is http://chuck-wright.com/calculators/insulpb.html). Page 10 has examples of the calculator in a spreadsheet format. The spreadsheet calculation is valid for gas heating and electric cooling, but online calculators accommodate other types such as heat pump or electric resistance heating. The calculators can be used for any materials, including windows, as long as the R-values (or u-factors) of the materials and assemblies are known.

Example Analysis of Energy Saving/Cost Benefit:
for adding insulation to a concrete wall

Note the following assumptions:

1. *The installed costs are 2012 prices. Add 2.5% for inflation for each additional year.*
2. *The following example explores the cost of installing one square foot of insulation to the concrete wall compared to the increased R-Value energy savings.*
    a. *The thermal mass of the concrete wall may impact the performance of the wall, but is not considered in this example. A professional analysis is recommended.*
3. *The savings achieved below assume that the concrete wall being insulated is not a basement wall and is exposed to outside temperatures. These calculations assume that all walls are the same regardless of orientation.*

R-Values in Example Analysis
Note that some R-Values require simple calculations to be in the proper form.

- *Poured concrete wall 8" thick* — *R = 0.64*
  R = 0.08/in x 8 inch wall = 0.64
- *Rigid insulation (beadboard)* — *R = 4/in*
- *Batt Insulation 3 5/8 in* — *R = 13*
- *2x4 Wood Studs* — *R = 4.38*

3. THE REALITIES OF COST / BENEFIT ANALYSES continued:

Example Analysis:

Note – Since the R-Value is the amount of heat flow resisted (in BTUs) per degree F per hour, one square foot of the new insulation should resist the flow of 8.56 BTUs per hour for every 1 degree difference in temperature (Delta T).

Calculating Cost Savings for Rigid Insulation:

1st Determine the Inputs in the blue box on the right and note the assumptions on page 7

2nd Using the Interactive Excel Tables on page 9, calculate the energy savings going from zero insulation wall assembly to an R-8.56 by doing the following

1. Calculate energy cost requirements for R-1 (assume R-1 rather than R-0 for more realistic values)
2. Calculate energy cost requirements for R-8.56
3. Subtract the smaller number from the larger number

Result (Total Cost Savings): is the amount of money saved for the given area over a course of a year. See the table on the following page.

Comparing Multiple Types of Insulation: Repeat the above steps as outlined for rigid insulation with the correct R-Value for the specific type and / or thickness of insulation desired. This can also be done for the same type of insulation with different thicknesses. It is important to note that comparing insulation is different than comparing whole wall assemblies. A variety of factors affect R-values for wall / roof assemblies. Walls framed with metal or wood studs cannot have continuous insulation due to the interruption of framing members, and therefore have less insulative value than walls with continuous insulation.

ASHRAE 90.1 is a resource document used to determine the R-value of walls and roofs, but the framing spacing and R-value of the insulation needs to be known. **The assembly R-value can be 1/2 or less than the insulation R-value itself because the framing members act as a conduit for heat transfer.** For example, a 6-inch wall with steel framing on 16 inch centers with R-19 batt insulation has an assembly R-value of only R-7.1 (per ASHRAE 90.1-2007 Table A9.2B). If energy transfer calculations are performed for this wall, it is important that R-7.1 is the R-value and not R-19.

Determine the following for rigid insulation:

1. *R-Values and installed cost for insulation application.*
   a. *Good source for R-Values:* www.coloradoenergy.org/procorner/stuff/r-values.htm
   b. *Good source for Installed Cost: RS 2012 Means Cost Data publication*
   c.

Material	*R-Value*	*Installed Cost/sf*
2" rigid insl.(4/in)	*8.0*	*$1.82*
5/8" gypsum bd	*0.56*	*$4.23*
"z" channels	*negligible*	*$1.23*
	8.56	*$7.28/sf*

2. *Heat and Cooling Sources: building is heated by natural gas and cooled by electricity*
3. *Location: Kansas City, MO*
4. *Cost of Electricity and Natural Gas:*
   a. *Good Source:* energy-models.com/tools/average-electric-and-gas-cost-state*, or actual utility bill*
   b. *Cost of natural gas = $0.72/therm*
      i. *(1 therm = 100,000 BTUs)*
   c. *Cost of electricity = $0.07/kWh*
5. *Total Annual HDD and CDD (2011 reference)*
   a. *Good Source:* www.degreedays.net/
   b. *Total Annual HDD(65 degrees): 5357*
   c. *Total Annual CDD(65 degrees): 1536*

3. THE REALITIES OF COST / BENEFIT ANALYSES continued

Example Analysis continued:

Comparison of Two Types of Insulation

Interactive Excel Table for 2” of Rigid Insulation added to a concrete wall
Inputs in yellow are the only numbers required (see previous page), all other inputs are automatically calculated.

DESCRIPTION	INPUTS	UNITS
Initial R-value	1	(hr x sf x degF)/BTU
Final R-value	8.56	(hr x sf x degF)/BTU
HDD	5,357	days x degF/yr
CDD	1,536	days x degF/yr
Heating Efficiency	0.8	% gas heating efficiency
Cooling Efficiency	3.5	COP
Cost of Gas	$ 0.80	$/therm
Cost of Electricity	$ 0.10	$/kWh
Area of Insulation	1	sf
Inverse of initial R-value	1.00	BTU/(hr x sf x degF)
Constant	24	hours/day
Initial Heating Energy	128,568	BTU/yr
Convert to Therms	1.61	therms/yr
Initial Heating Energy Cost	$ 1.29	$ heating/year
Initial Cooling Energy	36,864	BTU/yr
Convert to kWh	10.8	kWh
Initial Cooling Energy Cost	$ 0.31	$/year
Initial Total Cost Calculation	$ 1.59	$/year
Inverse of final R-value	0.12	BTU/(hr x sf x degF)
Final Heating Energy	15,020	BTU/yr
Convert to Therms	0.19	therms/yr
Final Heating Energy Cost	$ 0.15	$ heating/year
Final Cooling Energy	4,307	BTU/yr
Convert to kWh	1.3	kWh
Final Cooling Energy Cost	$ 0.04	$/year
Final Total Cost Calculation	$ 0.19	$/year
Total Cost Savings	$ 1.41	$/year

Interactive Excel Table for 3 5/8” of Batt Insulation
The only input to change is for the Final R-Value (shown in the lighter yellow).

DESCRIPTION	INPUTS	UNITS
Initial R-value	1	(hr x sf x degF)/BTU
Final R-value	13	(hr x sf x degF)/BTU
HDD	5,357	days x degF/yr
CDD	1,536	days x degF/yr
Heating Efficiency	0.8	% gas heating efficiency
Cooling Efficiency	3.5	COP
Cost of Gas	$ 0.80	$/therm
Cost of Electricity	$ 0.10	$/kWh
Area of Insulation	1	sf
Inverse of initial R-value	1.00	BTU/(hr x sf x degF)
Constant	24	hours/day
Initial Heating Energy	128,568	BTU/yr
Convert to Therms	1.61	therms/yr
Initial Heating Energy Cost	$ 1.29	$ heating/year
Initial Cooling Energy	36,864	BTU/yr
Convert to kWh	10.8	kWh
Initial Cooling Energy Cost	$ 0.31	$/year
Initial Total Cost Calculation	$ 1.59	$/year
Inverse of final R-value	0.08	BTU/(hr x sf x degF)
Final Heating Energy	9,890	BTU/yr
Convert to Therms	0.12	therms/yr
Final Heating Energy Cost	$ 0.10	$ heating/year
Final Cooling Energy	2,836	BTU/yr
Convert to kWh	0.8	kWh
Final Cooling Energy Cost	$ 0.02	$/year
Final Total Cost Calculation	$ 0.12	$/year
Total Cost Savings	$ 1.47	$/year

3. THE REALITIES OF COST / BENEFIT ANALYSES continued

Example Analysis continued:

Calculator Formulas Using 2" Rigid Insulation Example

The following spreadsheet shows how the formulas that result in the Total Cost Savings bottom line of $1.41 per year were derived. This spreadsheet can also be found in Appendix F for individual use.

DESCRIPTION	CALCULATION	INPUTS	UNITS
Initial R-value		1	(hr x sf x degF)/BTU
Final R-value		8.56	(hr x sf x degF)/BTU
HDD		5,357	days x degF/yr
CDD		1,536	days x degF/yr
Heating Efficiency		0.8	% gas heating efficiency
Cooling Efficiency		3.5	COP
Cost of Gas		$ 0.80	$/therm
Cost of Electricity		$ 0.10	$/kWh
Area of Insulation		1	sf
Inverse of initial R-value	=1/(Initial R-value)	1.00	BTU/(hr x sf x degF)
Constant	=hours in a day	24	hours/day
Initial Heating Energy	=1/(Initial R-value) x (hours in a day) x (Area of Insulation) x HDD	128,568	BTU/yr
Convert to Therms	=(Initial Heating Energy)/(100,000 x Heating Efficiency)	1.61	therms/yr
Initial Heating Energy Cost	=Therms/yr x $/therm	$ 1.29	$ heating/year
Initial Cooling Energy	=1/(Initial R-value) x (hours in a day) x (Area of Insulation) x CDD	36,864	BTU/yr
Convert to kWh	=Initial Cooling Energy / 3,412	10.8	kWh
Initial Cooling Energy Cost	=kWh/COP x $/kWh	$ 0.31	$/year
Initial Total Cost Calculation	=Initial Heating Energy Cost + Initial Cooling Energy Cost	$ 1.59	$/year
Inverse of final R-value	=1/(Final R-value)	0.12	BTU/(hr x sf x degF)
Final Heating Energy	=1/(Final R-value) x (hours in a day) x (Area of Insulation) x HDD	15,020	BTU/yr
Convert to Therms	=(Final Heating Energy)/(100,000 x Heating Efficiency)	0.19	therms/yr
Final Heating Energy Cost	=Therms/yr x $/therm	$ 0.15	$ heating/year
Final Cooling Energy	=1/(Final R-value) x (hours in a day) x (Area of Insulation) x CDD	4,307	BTU/yr
Convert to kWh	=Final Cooling Energy / 3,412	1.3	kWh
Final Cooling Energy Cost	=kWh/COP x $/kWh	$ 0.04	$/year
Final Total Cost Calculation	=Final Heating Energy Cost + Final Cooling Energy Cost	$ 0.19	$/year
Total Cost Savings	=Difference of Final Energy Cost and Initial Energy Cost	$ 1.41	$/year

4. GENERAL CONSIDERATIONS FOR ENERGY USE IN YOUNGER HISTORIC BUILDINGS

- Standards for thermal comfort and adequate lighting have become more stringent since most historic buildings were constructed.
- Many buildings from the 1950s and 1960s that are becoming eligible for the NRHP were designed to rely heavily on energy consumptive HVAC and lighting.
  - As the provision of mechanical heating ventilating and air conditioning became more commonplace, buildings started to cease being designed to take advantage of cross ventilation.
    - Generally, buildings that were designed to take advantage of the new technology of HVAC tended to be “thicker” since they did not need natural ventilation.
  - Artificial Lighting became an accepted approach because energy in the 1950s and 60s was inexpensive.
    - Because there was no need for windows for lighting and ventilation, these “thicker” buildings used a great deal of energy on lighting.
    - The excess heat of the artificial lighting increased the cooling load on the building. This increased load was acceptable, however, because energy was cheap.

Department of Defense Environmental Research Programs:
SERDP and **ESTCP** are the Department of Defense's environmental research programs, harnessing the latest science and technology to improve DoD’s environmental performance, reduce costs, and enhance and sustain mission capabilities.

The Programs respond to environmental technology requirements that are common to all Military Services, complementing the Services’ research programs.

For more information, see: http://www.serdp.org/Program-Areas/Resource-Conservation-and-Climate-Change/Cultural-Resources/(language)/eng-US

Part II, The Design Guidelines, includes forty topics selected for their high energy saving potential. The reader should note that the numbering system for the Guidelines is not completely sequential. As noted in the Introduction, the Guidelines are arranged based upon the Construction Specifications Institute (CSI) Master Format. Where there is no Guideline included from a particular CSI division (the first two numbers), the division number is omitted. For example, there are no Guidelines included from Division 09, Finishes.

CSI DIVISIONS

00 Procurement and Contracting Requirements	INCLUDED
01 General Requirements	INCLUDED
02 Existing Conditions	INCLUDED
03 Concrete	INCLUDED
04 Masonry	INCLUDED
05 Metals	INCLUDED
06 Wood, Plastics, Composites	INCLUDED
07 Thermal and Moisture Protection	INCLUDED
08 Openings	INCLUDED
09 Finishes	OMITTED
10 Specialties	OMITTED
11 Equipment	OMITTED
12 Furnishings	INCLUDED
13 Special Construction	OMITTED
14 Conveying Equipment	OMITTED
22 Plumbing	INCLUDED
23 HVAC	INCLUDED
26 Electrical	INCLUDED
28 Electronic Safety and Security	OMITTED
31 Earthwork	OMITTED
32 Exterior Improvements	INCLUDED
33 Utilities	OMITTED

APPROACH: This Guideline outlines key steps at the beginning of the project that will help DoD Cultural Resource Managers (CRMs), Facility Managers and the Design Team meet Historic Preservation and Energy Saving design goals. Many installations have their own CRMs who coordinate Section 106 consultations with the State Historic Preservation Officer (SHPO). Any project which affects historic properties must be coordinated with the CRM. CRMs are also helpful in collecting historic information about the building.

***Step 1: Become informed regarding Federal Law and Policies related to historic structures and energy conservation*.**

A good introduction to this topic can be found in the Advisory Council on Historic Preservation's publication, "Sustainability and Historic Federal Buildings", www.achp.gov/docs/SustainabilityAndHP.pdf, (ACHP, et al, 2011).

This document answers basic questions such as:

- What is a "Historic Property"?
- What are the major, applicable laws and policies related to Historic Structures and Energy Conservation?
- What is "Historic Character"?
- What is "Historic Integrity"?
- What is a Life-Cycle Cost Analysis?
- What are the Secretary of the Interior's Standards that govern rehabilitation of federal historic structures?
- What is the Section 106 compliance process? (See page 18 for more information about Section 106.)

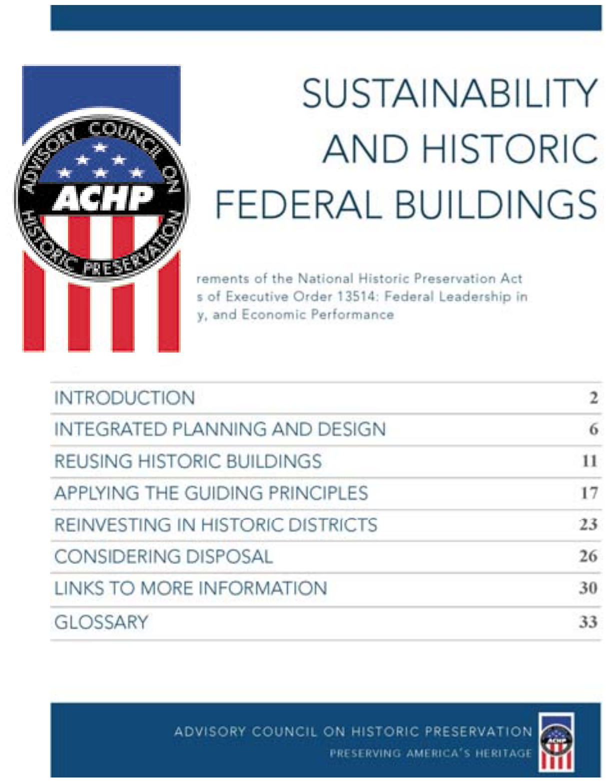


Figure 00 01-1

Step 2: Understand the current energy use of the historic structure.

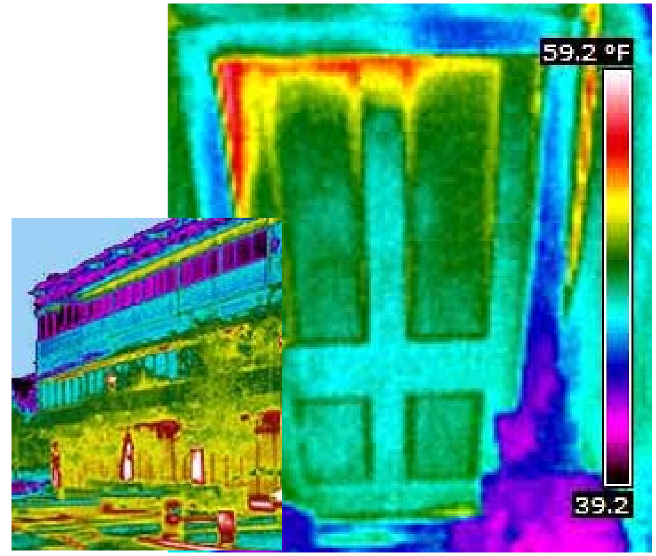
In order to know what energy savings should be accomplished in the remodel of a historic structure, it is necessary to establish the pattern of energy use for the building in its current state. This pattern of use will be compared to energy use when the project is occupied to determine the extent of energy savings. Many factors can affect that comparison, especially if the functions in the building are different before and after remodeling. Regardless, it is important to establish the "before" pattern of energy use.

ENERGY AUDIT: The best way to understand how energy is being used in an existing building is to have a qualified professional with experience in historic construction conduct an energy audit. Energy auditors will analyze energy bills, conduct heat gain and loss studies, perhaps use thermograph imagery to see where energy is escaping, and other diagnostic methods to determine where and how energy is being used. The results of the energy audit should indicate which improvements may accomplish the most in reducing energy use. Energy auditors can provide guidance on which strategies are the most cost effective and which strategies will produce the most comfortable environment for the occupants.

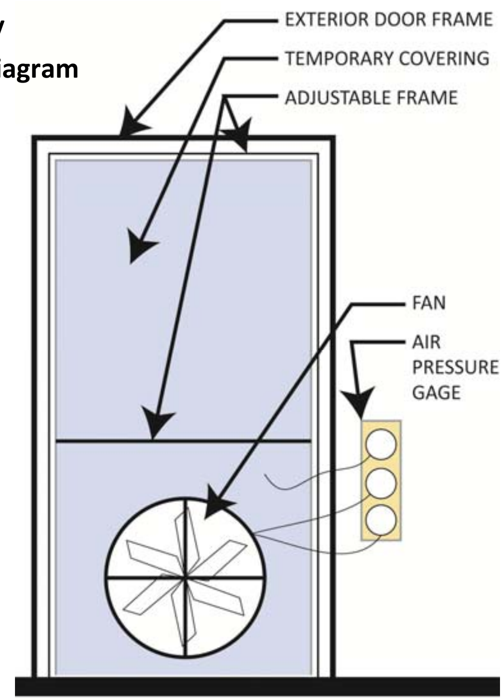
Note: Because many military installations do not meter buildings separately, it may not be possible to determine existing energy use from energy bills. If the building is in use it may be possible to add line meters and monitor building energy use during project planning.

- **Types of tests:**
  - The most common are Infrared Thermography (thermal imaging) and air infiltration (blower door) tests.
  - Depending on resources and budget, computerized energy analysis, computerized hygrothermal modeling and thermal transfer modeling can also be done.
- **Conducted When:** should be when there is a significant temperature difference between the interior and exterior of the structure (mid-summer and/or mid-winter)
- **Additional**: periodic monitoring regardless of type of insulation should be done to ensure that the insulation is performing the way it was intended.
  - Should provide information on whether the building already has insulation, how much (R-value and thickness) and where.

Figure 00 01-2 Thermographic Imagery



Air Infiltration/ Blower door Diagram
Figure 00 01-3



Step 2: Understand the current energy use of the historic structure continued.

If funds are not available for a professional energy audit, the facility manager can collect energy use data by recording the energy bills for the most recent 12 month period of building use. (See Note on previous page.) The measure of energy use that is common is the amount of British Thermal Units (BTUs) used per square foot of building per year: BTU/sf/year. This informal study can provide a base line of energy use for the building; however, it will not be specific about where energy is being used efficiently or inefficiently.

A simplified description of the method of determining the base line follows:

a. Determine the total Kilowatt Hours (Kwh) of electrical use from the electric bills.
b. Determine the total Therms of gas use from the gas bill.
c. Determine the total gallons of fuel oil used from the fuel oil bill.
d. Refer to the Appendix D, Conversion Factors, in this study to determine the way to convert Kwh, therms and gallons of fuel oil to BTUs. Convert all the energy uses and total them up.
e. Determine the square footage area of the building.
f. Divide the total energy use in BTUs by the area of the building to determine the BTUs / square foot for the year. This number is the base line energy use.

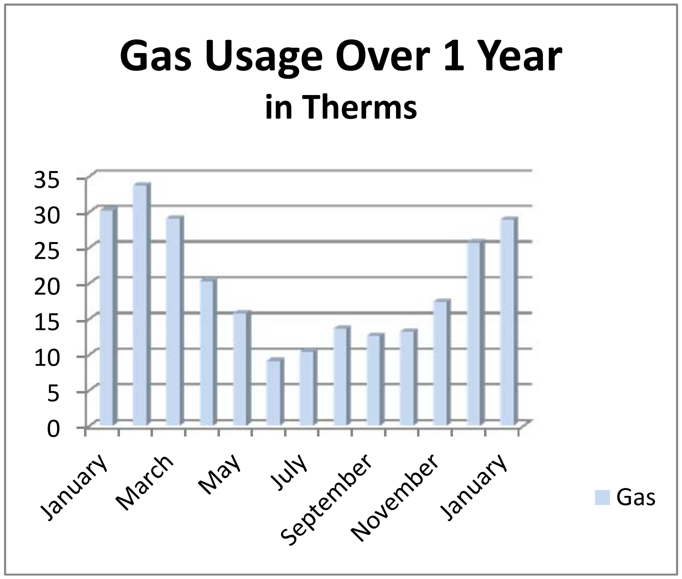


Chart 00 01-1

The exercise above assumes that the building to be remodeled is currently in use. This exercise would not be applicable for a building currently not in use.

Step 3: Collect information on the history of the building's development.

The more you and your architect understand about the building and its structural history, the fewer surprises will present themselves during construction. Surprises may require expensive change orders, a circumstance worth avoiding. If funds are available, the sources and types of information can be researched by consultants. If funds are not available, many of these sources can be contacted or researched by staff members of the agency.

Coronado School, Original Drawings

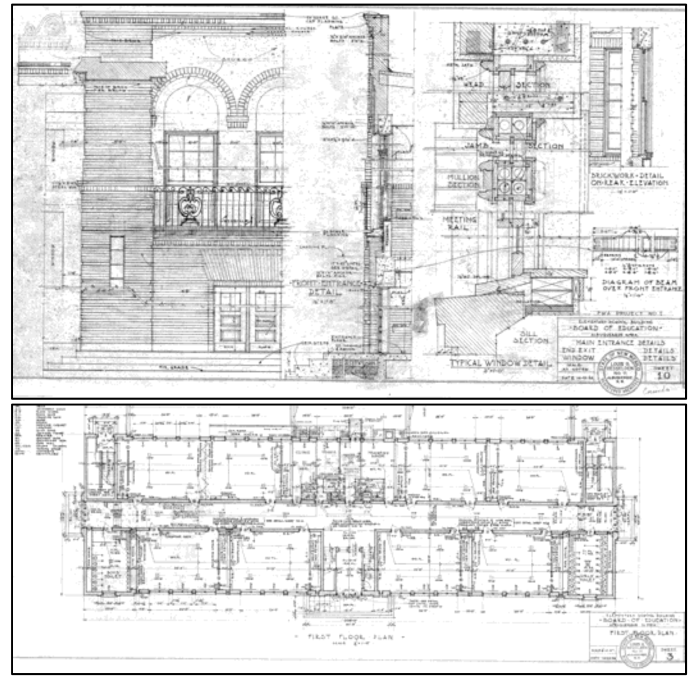


Figure 00 01-4 Courtesy of Albuquerque Public Schools

<u>Useful types of information include:</u>

a. Architectural / engineering drawings for the original building and remodels:

These drawings provide useful information on materials, measurements, methods of construction, and intentions of the original design and subsequent remodels. They can reveal hidden conditions that can eliminate the need for destructive investigations. They can also reduce the cost of the preparation of drawings of the existing conditions that will be the starting point for a remodeling project.

It is important to remember that all the projects that are drawn and cataloged in an archive are not necessarily executed. Also, some remodels are drawn, constructed, and later removed. The architect will need to verify the drawn record with the existing installation.

b. Archives of procurement documents such as contracts for architects, engineers, and contractors; or invoices from materials suppliers, and installers can be useful. These documents can indicate information as varied as dates in the chronology of the building's changes, locations of quarries for stone, or decorative ironwork manufacturers.

Step 3: Collect information on the history of the building's development continued.

c. Photographs taken of the building exterior or interior:

Photographs that show any portion of the building can be helpful in determining the sequence of changes to the building. Photos of people standing at the main entry or in the major interior space may have been intended to commemorate an event. They also reveal the architectural conditions at the time of the photograph. If the date for the image is known the information is even more valuable. Analysis of the photos can reveal the sequence of changes to the building and provide clues to determining why changes were made. These images can verify whether the drawings for changes were executed or not.

The photographs and drawings collected can be archived and used for exhibit and informational publications to celebrate the opening of the building when the project is completed.

Coronado School, 1939 Photograph

Figure 00 01-5
Courtesy of Georgia Otero (fifth from the left)

<u>Sources of information include, but are not limited to:</u>

a. Every state has a State Historic Preservation Officer (SHPO) that has information about properties on the National Register of Historic Places and the State Register, if one exists.
b. The agency that is responsible for the building may have document archives.
c. Local libraries and museums.
d. Local historical societies.
e. The state where the building is located may have a state archive and/or records center that houses historical documents.

Step 4. Select Design Professionals with experience with historic preservation projects

Most procurement processes for architectural services allow for selection criteria defined specifically for the project at hand. Experience with historic preservation projects and energy conservation in historic buildings should be two criteria for a project of this nature.

GUIDELINE DESCRIPTION: This Guideline provides guidance for working with the State Historic Preservation Officer (SHPO) or his or her designee assigned to the project. It covers the preparation for initial meetings with the SHPO, involvement of the Cultural Resource Managers (CRMs), Design Team, project managers, and building managers. On installations with Cultural Resource Management Branches/Sections/ Offices, they are the ones who work with and initiate consultation with the SHPO. If there is no CRM office someone usually in Environmental is designated to consult with the SHPO.

RELATED GUIDELINES:
- 00 01 Project Organization
- 00 03 Strategies for Major Preservation Issues

Why is the SHPO involved?
The National Historic Preservation Act (NHPA) of 1966, as amended, is the guiding force behind the federal historic preservation policy. In Section 1(b), the Act states in part:
- The spirit and direction of the Nation are founded upon and reflected in its historic heritage;
- The historical and cultural foundations of the Nation should be preserved as a living part of our community life;
- Historic properties significant to the Nation's heritage are being lost or substantially altered, if inadvertently, with increasing frequency; and
- The preservation of this irreplaceable heritage is in the public interest so that its vital legacy of cultural, educational, aesthetic, inspirational, economic, and energy benefits will be maintained and enriched for future generations of Americans.

The SHPO is the local official responsible for enforcing the NHPA. While SHPOs are usually state officials, the federal government contracts with SHPOs to review projects that use federal funds. Some Native American or First Nation tribes have an equivalent official that fills the same role on native owned lands. They are called Tribal Historic Preservation Officers (THPO). In reviewing federally funded projects, the SHPO or his or her designated staff is working on behalf of the federal government. In some states, there is a citizens' committee, often appointed by the governor, which has a say in the operations and decisions of the SHPO's office. In most jurisdictions, the SHPO is responsible for the Section 106 review (see box).

SECTION 106 REVIEW
Section 106 directs federal agencies to consider how their undertakings affect historic properties. The federal Advisory Council on Historic Preservation's (ACHP's) regulations implementing Section 106, "Protection of Historic Properties" (36 CFR Part 800), outline a process for the consideration of alternatives that promote preservation and offer the public and stakeholders the opportunity to influence federal decisions:

- *Initiate the review and determine if it applies to a given program or project,*
- *Identify historic properties that may be affected,*
- *Assess the effects of the project on the identified historic properties,*
- *Resolve adverse effects by exploring alternatives to avoid, minimize, or mitigate the effects.*

This review process encourages, but does not mandate, preservation. When historic properties will be adversely affected by a federal undertaking, the review usually ends with a negotiated and legally binding agreement that outlines how the affects will be resolved.

For more information, see: http://www.achp.gov and for how-to guidance including NHPA Sec 106 and treatment of historic buildings, see: https://cs.eis.af.mil/a7cportal/CEPlaybooks/AM/EM/CRM/Pages/default.aspx .

Common Terms Used by the SHPO as defined by the NHPA:

The following are used to describe or discuss properties that fall under the protection of the NHPA:

Building– a category of historic properties. Buildings refer to places that shelter human activity.

Eligible – the status of a structure 50 years or older that has not been placed on the NRHP, but is deemed by the SHPO to be eligible. A building or structure that has been declared "eligible" for the NRHP is afforded the same protections as a registered building.

Character defining features – aspects that are integral to a building or structure's historic and architectural significance and integrity. They are usually physical aspects such as the overall shape, design, materials, windows, craftsmanship, decorative features and landscape context. The SHPO determines what features are "character defining features."

Historic resource / historic property – means any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the NRHP.

Historic district – a significant concentration, linkage, or continuity of sites, building, structures, or objects united historically or aesthetically by plan or physical development. A single building might not be eligible by itself, but might require the SHPO's review because it is in a historic district, and it is designated as contributing to that district.

Individually eligible property – a historic property, or object that meets the National Register criteria for designation. If it is a building or structure, it may include interior and exterior features. It could also include landscaping features immediately surrounding the property.

Structure – a category of historic properties, for purposes other than human shelter.

Site – a category of historic properties. Sites are locations of significant events with historical, archaeological, or cultural value regardless of whether or not there is a standing structure.

Undertaking – A project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a federal agency, including those carried out by or on behalf of a federal agency; those carried out with federal financial assistance; and those requiring a federal permit, license, or approval (36 CFR §800.16(y)).

Common Abbreviations Used by the SHPO:

ACHP – Advisory Council on Historic Preservation

NHPA – the National Historic Preservation Act of 1966

NRHP – the National Register of Historic Places, the National Register

SHPO –State Historic Preservation Officers

THPO –Tribal Historic Preservation Officers

For more definitions see the Glossary at www.achp.gov/docs/SustainabilityAndHP.pdf page 30.

When should the SHPO become involved?

The SHPO's office should be contacted at the very beginning of a project when a building over 50 years old is proposed for remodeling or other major change. Sometimes, buildings that are younger than 50 years old require consultation with the SHPO if they are associated with historic sites or districts. The term used for remodeling or other change is called an "undertaking." Undertakings using federal funds are subject to review by the SHPO.

The reasons to contact the SHPO at the very beginning of the project are:

- All the federal regulations can be explained.
- By reaching an accord with the SHPO, the status of the building to be remodeled can be determined.
- If the building is determined to be on the NRHP or eligible for the register, the character defining features of the building can be identified. These features need to be protected if at all possible in the renovation process.
- A schedule of reviews can be set up so that the project schedule is not adversely impacted by these required reviews.
- An early meeting shows respect for the responsibilities of a fellow federal representative. It indicates a commitment to cooperation that all parties appreciate.
- The SHPO has experience with professionals whose expertise may be helpful to the project. The SHPO may also know of buildings with similar problems that have been successfully rehabilitated.

Understanding the Role of the Secretary of the Interior's Standards for Rehabilitation:

The National Park Service (NPS) is the federal agency that has developed the Secretary of the Interior's Standards for Historic Preservation, Rehabilitation, Restoration and Reconstruction to guide projects that are of value to the history of the American people. The NPS has the last word on review of preservation projects that use federal funding. For most issues, the decision of the SHPO is final, but occasionally, decisions are moved up to the regional office of the NPS. Many federal agencies have employees that are designated to work with the NPS and help provide guidance in working with historic properties. In the Department of Defense there are Cultural Resource Managers (CRMs) that are appointed for larger installations.

Secretary of the Interior's Standards for Rehabilitation:
www.nps.gov/tps/standards/rehabilitation.htm
The Secretary of the Interior's Standards for Rehabilitation, codified as 36 CFR 67, are regulatory for federal undertakings.

Secretary of the Interior's Guidelines for Rehabilitation:
www.nps.gov/tps/standards/rehabilitation.htm
The Guidelines assist in applying the Standards to rehabilitation projects in general.

"The National Register of Historic Places is the official list of the Nation's historic places worthy of preservation. Authorized by the National Historic Preservation Act of 1966, the National Park Service's National Register of Historic Places is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect America's historic and archeological resources." (National Register of Historic Places. 2011)

Checklist for Initial Meeting with SHPO:

At the initial meeting with the SHPO the following can take place:

- Exchange contact information
- Present any historic information gathered on the building (See Guideline 00 01, Project Organization; Step 3: Collect Information on the history of the building's development,)
- Ask if the SHPO has photographs and other information on file on the building that can be copied.
- Explain the status of the project. Is it funded? Funding is being requested? What is the schedule? Is the budget tight or ample?
- Request concurrence with the following:
    - NRHP listing or eligibility for the building
    - Identification of character defining features and other areas of concern from the SHPO's perspective. Ask for these in writing so that they can be transmitted later to the Design Team, and perhaps even included in the Request for Proposals for the Architect.
- Discuss the impact of any possible energy saving approaches that have been mentioned, or perhaps suggested by the Energy Auditors (See Guideline 00 01, Project Organization; Step 2: Understand the current energy use of the historic structure.)
- Discuss the schedule for the SHPO's reviews. What is the submittal content?
- Invite the SHPO or his or her representative to visit the site.

With this initial meeting you will have received valuable information and established a communication process and can avoid many schedule interruptions later.

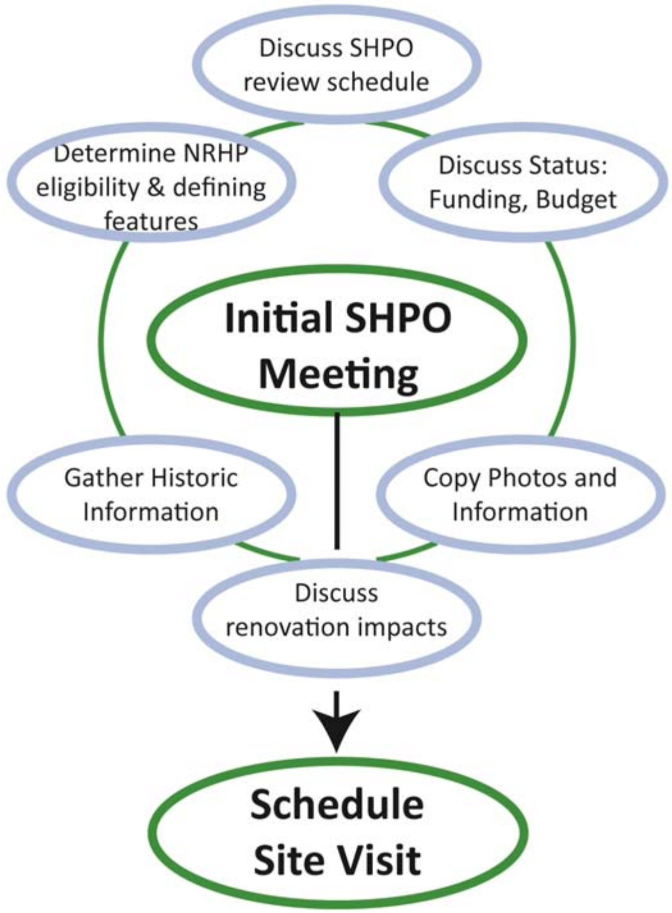


Figure 00 02-1

GUIDELINE DESCRIPTION: This Guideline introduces the basic physics of heat transfer in buildings, and the strategies that historic buildings used to minimize energy use. It describes the changed ideas of human thermal comfort and illumination expectations. It discusses how to make use of the energy saving strategies inherent in many historic buildings, refers to the strategies described in the Guidelines in this report, and suggests criteria for selecting strategies for energy saving in the upcoming rehabilitation project.

RELATED GUIDELINES:

- 00 01 Project Organization
- 00 02 Working with State Historic Preservation Officer (SHPO)
- 23 08 Selecting HVAC Systems

BACKGROUND CONSIDERATIONS:

A Brief Introduction To How Buildings Use Energy:

Basic physics

- Heat is energy. Cold is the absence of heat. Instead of saying "It is really cold in here," one would be more accurate to say, "There is really an absence of heat in here."
- 2nd Law of Thermo Dynamics (Thermo = heat; Dynamics = moves): Heat flows from a region of high temperature to a region of low temperature.
- How heat transfer is measured?

British Thermal Units per hour per square foot of area per °F
written
$BTU/hr/ft^2/°F$

- Heat transfers at different rates through different materials. The thickness of the material makes a difference, too. We measure the resistance of a material to heat transfer with the material's "**R factor**." An insulation pad with an R factor of 19 resists heat transfer better than an insulation pad with an with an R factor of 6. The higher the number, the better the insulator pad.

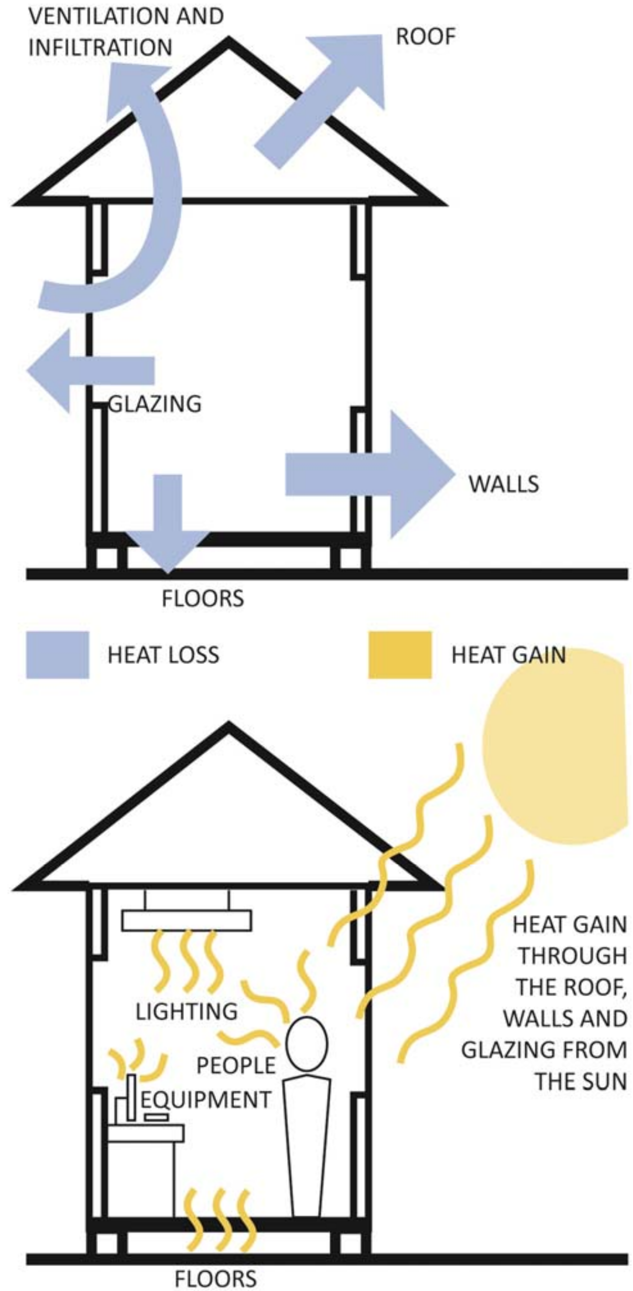


Figure 00 03-1

BACKGROUND CONSIDERATIONS continued:

How Historic Buildings Approached Energy Use: Prior to the post WWII era; most buildings relied on the sun for light and sometimes heat during the day, and breezes and massive construction to temper the warm temperatures of summer. Buildings were designed to use as little energy as possible because energy was hard to obtain. Often heat energy was wood obtained from a near-by source. Light energy was often from burning oil of some type, also difficult to obtain. Gradually, as local fuel sources were used up, people began importing fuel from farther and farther away.

In warm climates, buildings were cooled by designing for cross-ventilation systems, including porches. Porches shaded the walls so that the heat of the sun did not hit directly on the wall. The porches were useful as shaded functional spaces, as well.

The common assumption was that no one would use energy for lighting during the day. Buildings had lots of windows. Buildings were narrow so that natural light could get to the center of the interior spaces; we could say they were “skinny” buildings. When lighting was used in the evenings, it was often used sparingly for specific tasks. As the electric lighting technology developed expectations for general as well as task lighting increased.

Other energy conservative approaches of historic buildings included using the direct gain of the winter sun on the south side of the building (in northern latitudes) to warm the interior spaces during the day. Deciduous trees, planted on the west side of a building, could shade the west wall during the summer and allow the sun to hit the wall in the winter.

The WWII industrial efforts developed efficient transportation routes and plentiful sources of fuel. Most fuel sources were relatively inexpensive compared with earlier times or today. Air conditioning became an accepted initial construction expense in exchange for greater comfort levels in the 1950s. Electric lighting during the day also became an acceptable expense. Many buildings built during the 1950s and 1960s had fewer windows, were completely air conditioned and de-humidified, if necessary, and anticipated the use of electric lighting during the full working day. Some of the buildings of this mid-century era are now eligible for the National Register of Historic Places.

The oil embargo of the early 1970s changed people’s attitudes toward energy use. Many of the “old ideas” began to find their way back in the design of buildings. Buildings built before the 1950s already have in their architecture an approach to energy conservation that we should preserve and enhance with modern technologies.

Figure 00 03-2

From Fort Bliss Archives: This 1910 photo is of a building at Ft. Bliss, Texas. It had porches on the west side, many windows, was heated by fireplaces and ventilated by opening the windows. It is currently used as an office building meeting all modern expectations of comfort having been retrofitted with modern heating and cooling.

BACKGROUND CONSIDERATIONS continued:

Making Use of Historic Energy Strategies: Physics does not change over time. While the expectations of occupants are more stringent, many of the energy characteristics of historic buildings can still be useful today, enhanced by new technologies and equipment.

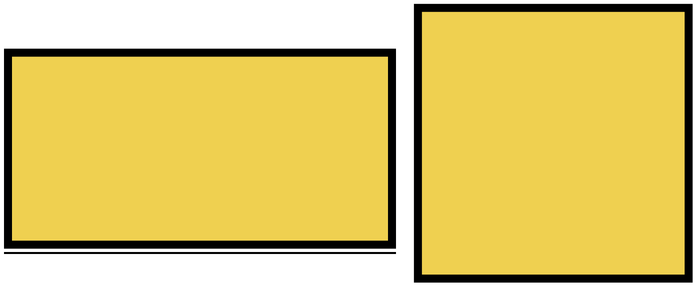


Figure 00 03-3
Figures A and B contain the same area. Fig. A has approximately 16% more perimeter than Fig B

Building Shape: The "skinny buildings" that were designed with lots of windows to provide natural light to the interior of the building are still an excellent strategy today. While the Secretary of the Interior's Guidelines for Historic Preservation strongly advocate for the reuse of historic windows whenever possible, new back-up windows can often be added and make use of new glass products that block a certain amount of heat transfer (see Guideline 08 52). Back-up windows also slow down heat transfer through the window area.

The "skinny buildings" have a longer perimeter than a building of equal area that is a square. A lengthy perimeter allows for more heat transfer at the building walls. To deter this heat transfer, insulation can often be added to the walls, most likely to the interior of the walls to allow the historic facade to be unchanged (see Guidelines 03 31, 04 21, 06 81 and 07 21).

Windows: There are numerous studies that contend that workers are more efficient with access to natural light. In contemporary buildings much of the energy use is expended on cooling the space that is heated by the electric lighting system. Both are good arguments for using buildings with many windows and little need for artificial lighting. The unwanted direct gain of the sun at certain times can be addressed with shades and the new types of glass in back-up windows. (see Guidelines 08 01, 08 02 and 08 52.)

Wall Thickness: Since the thickness of a wall of brick or masonry worked to slow down the heat transfer, a careful analysis by professional designers can retain some walls as un-insulated to the overall advantage of the building's energy use.

Building Orientation: Historic buildings were often oriented to take advantage of the winter sun and summer shading. Such features should be retained and celebrated.

High Ceilings: Many historic buildings have high ceilings to allow the summer heat to move to the top, unoccupied area, naturally. Sometimes these areas were ventilated by transom windows above doors. These methods still work and can usually be retained in renovations.

Figure 00 03-4
1851, Joseph Paxton, the Crystal Palace, Hyde Park, London

Making Use of Today's Energy Strategies:

Historic preservation and energy conservation measures can often work synergistically. Because historic buildings, at least up until the 1950s, assumed features like natural lighting and low energy use, restoring features can often reduce energy use. The major, modern improvements include better insulation of the building envelope and more efficient heating. The additional expectation of mechanical cooling has added an energy requirement that must be addressed as efficiently as possible. Today's energy strategies can enhance the energy conservations strategies of old. They include:

- Better insulation to prevent heat transfer in walls, ceilings, and floors.
  - Guideline 03 31 Insulating Concrete Walls
  - Guideline 04 21 Insulating Masonry Walls
  - Guideline 06 81 Insulating Wood Structures
  - Guideline 07 01 Adjusting Historic Features for New Insulation on Roofs
  - Guideline 07 21 Thermal Insulation
  - Guideline 07 31 Insulation for Sloped Roofs
  - Guideline 07 51 Insulation for Flat Roofs
- New types of glazing (if historic glazing is not in place) or installing back-up windows.
  - Guideline 08 52 Wood Storm Windows
- Reducing air infiltration at building material joints.
  - Guideline 07 92 Using New Joint Sealants on Historic Components
  - Guideline 08 01 Increasing Energy Efficiency in Historic Windows
- More efficient lighting and the use of task lighting.
  - Guideline 08 02 Natural Lighting
  - Guideline 26 51 High Efficiency Lighting
- More efficient heating, ventilating, and air conditioning (HVAC) systems.
  - Guideline 23 08 Selecting HVAC Systems
  - Guideline 23 11 HAVC Interior Placement, and Guideline 23 12 HVAC Exterior Placement
- More efficient electrical supply.
  - Guideline 26 01 Solar Photovoltaic Panels
- More efficient hot water supply
  - Guideline 22 33 Hot Water Energy Conservation

Specific Strategies for Your Historic Building:

Selecting the specific energy saving strategies for your historic building will make use of the Energy Audit suggested in Guideline 00 01, Project Organization. It makes sense to devote rehabilitation resources (funding and time) to address the areas of greatest energy waste. Usually, but not always, reducing the heat transfer of the building shell (roof, walls, and floor) is the number one priority. If the building shell is leaking energy like a sieve, then resources spent on a more efficient heating/cooling system is a waste of money and energy.

The Architect/Engineer Design Team will have recommendations based upon their experience in historic preservation and energy savings. In discussing strategies with Design Team representatives, consider the following criteria:

1. Does the strategy address the areas of the building where the most energy is currently being wasted?
2. What energy saving strategies respect the building's character defining features most effectively?
3. What are the most cost effective strategies that address criteria 1 and 2?

Figure 00 03-5

Figure 00 03-6

South Carolina Navy Yards, Building 76
Repurposed for offices and testing labs.

GUIDELINE DESCRIPTION: The purpose of this Guideline is to make readers aware that there are ways to save energy that are most efficient at the multi-building, or planning scale. Most historic structures on military installations are part of a wider group of structures and infrastructures (streets, utilities, waste removal and disposal, etc.). This Guideline describes some of the most common energy saving approaches at this larger scale and provides the reader with the vocabulary associated with these approaches. The information provided in this Guideline are ideas; it is up to the Design Team to ensure that the specific implementation meets UFC requirements.

RELATED GUIDELINES:

- 00 02 Working with State Historic Preservation Officer (SHPO)
- 00 03 Major Preservation and Energy Issues.
- 07 52 Green Roofs on Historic Buildings
- 26 01 Solar Photovoltaic Panels

GENERAL NOTES:

- For the purposes of this Guideline, infrastructure includes power (electric and gas) distribution; domestic water supply; storm and waste water; sanitary sewer; garbage collection and recycling. All of these infrastructure components use energy.
- This Guideline will look at the following topics:
  - Power Generation:
    - Solar – Photovoltaic Production of Electricity
    - Wind Generation of Electricity
    - Bio Mass Generation of Electricity and Gas
  - Water Supply and Waste Water Treatment
    - Supply water
    - Storm water
    - Sanitary sewer
- On some occasions, larger scale improvements to entire historic districts may be more efficient and have less impact on individual historic structures.

Figure 01 01-1 15MW array on 140 acres of unused land at Nellis AFB. Arrays can be located away from historic districts so as to not disturb the historic character.

Figure 01 01-2 Two 1.6 megawatt utility-scale wind turbines at Cape Cod Air Force Station, MA

GENERAL NOTES continued:

- If well planned, infrastructure improvements to historic districts can produce significant energy savings, in keeping with recent technological developments.
  - An initial step is an energy audit of the area under consideration (a historic district or wider area) to determine the basic energy use patterns of that area.
- Remote locations where fuel needs to be transported over long distances or to areas not served by public utilities are ideal for a wide-scale approach to infrastructure energy improvements.
- Locations where renewable energy sources are readily available are also ideal for a wide-scale approach to infrastructure energy improvements.
- Nearly half of the electricity generated in the USA in 2009 was lost in transmission and distribution. Because a great deal of energy is lost in transmitting electricity over long distances, generating power close to the point of use saves energy. (U.S. Department of Energy, "Buildings Energy Data Book," 2012).
- Determine with the SHPO, early in the process, the character defining features of the Historic District to be preserved. For example, a boulevard with rows of mature trees might be a character defining feature for a historic district. Replacement of power distribution, or sewer lines, etc. would need to preserve the boulevard.
- Community or neighborhood scale projects will require early involvement of consulting engineers and preservationists to determine feasibility of the approaches. Aggregating projects may have economies of scale, but the individual circumstances of any location may not support the initial construction costs or life cycle pay-offs.
- Because of the complexity and the variety of historic districts, larger scale improvements require the services of engineers familiar with the specific scale of public works.

GENERAL HISTORIC PRESERVATION EFFECTS:

- The scale of energy efficient infrastructure development might be larger than a single historic district. If such a condition arises, improvements that might be objectionable near or within a historic district may be used outside of it without adverse effect to the historic resources.

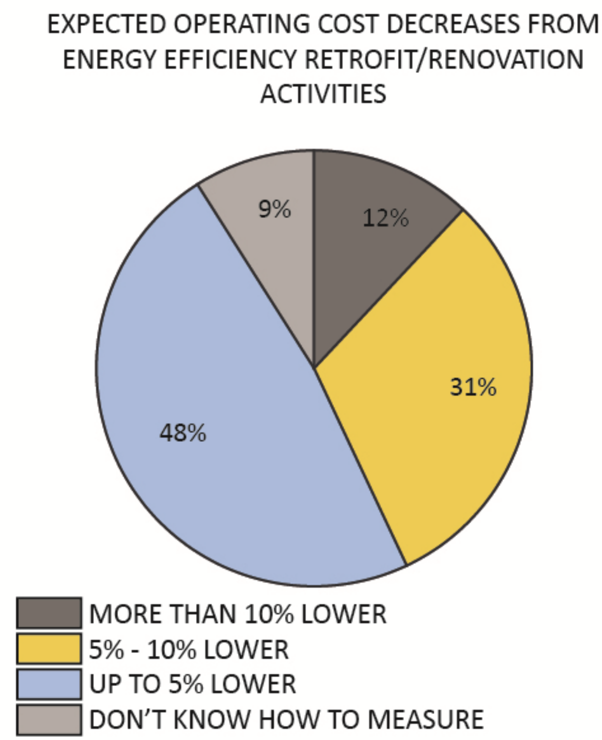


Chart 01 01-1

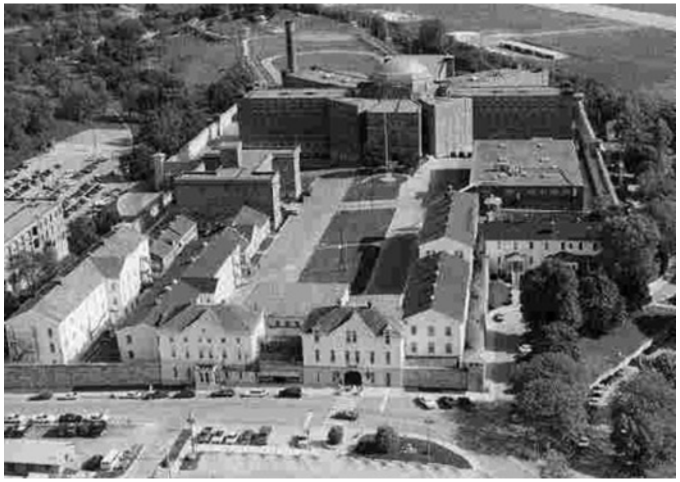


Figure 01 01-3 Aerial view of Ft. Leavenworth, KS

GENERAL ENERGY SAVINGS POTENTIAL:

- The prediction of energy savings will be very general because of project complexity.

CONSIDERATIONS FOR ADDING A PHOTOVOLTAIC PANEL ARRAY IN OR NEAR A HISTORIC DISTRICT:

- **Approach:**
  - Photovoltaic (PV) panels convert the energy of the sun into electricity.
  - Carefully review Guideline 26 01 Solar Photovoltaic Panels for a more in depth discussion of how Photovoltaic Panels work.
  - In areas where electricity is generated by others, PV systems can be connected to that grid so that electricity is available from the grid at night, on long winter nights, etc. In some areas, excess electricity generated by PV arrays can be sold back to the public provider. This resale is called "net metering."
  - In areas where there is no power generated by others, PV systems are connected to a range of storage batteries that are charged during the day and are then drained at night. Contingencies for multiple cloudy days or long winter nights must be planned.
  - "Commercial Scale Systems:" Neighborhood scale arrays can be used in historic districts where centralizing the installation of photovoltaic panels might be more efficient, in terms of construction and distribution of power, than using separate panel arrays on individual building or sites.
  - On these occasions, the visual impact of the panel arrays might be better controlled in one area where it could be screened with fencing or landscaping.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Large arrays of photovoltaic panels should not be located near individual historic properties unless they can be visually screened.

Major Resource for the Process:
A Kandt et al., "Implementing Solar PV Projects on Historic Buildings and in Historic Districts" (National Renewable Energy Laboratory, September 2011), http://www.nrel.gov/docs/fy11osti/51297.pdf

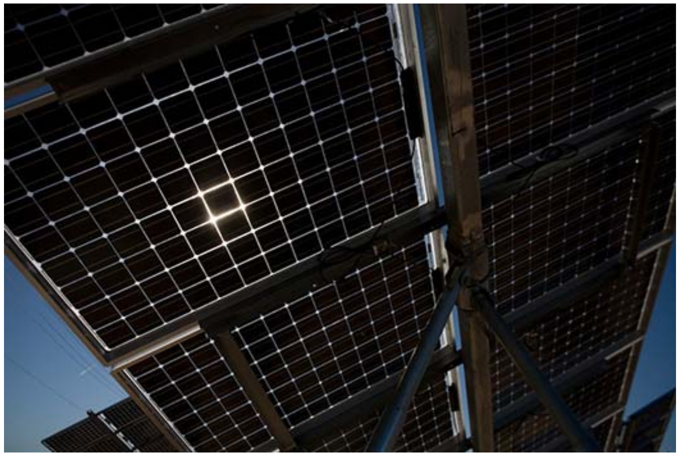


Figure 01 01-4 Back side of solar panel

CONSIDERATIONS FOR ADDING A PHOTOVOLTAIC PANEL ARRAY IN OR NEAR A HISTORIC DISTRICT continued:

- **Historic Preservation Effects continued:**
  - Consider location of new power lines and supports to minimize visual impact.
  - Ideally, lines will be buried in historically sensitive locations. Burial of lines is more expensive, but has the advantage of protecting lines from ice storms.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step-by-step example of how a calculation can be done.
  - Energy represents about 19% of total expenditures for maintaining a typical office building.
  - The U.S. Energy Information Association monitors electrical usage in the US. In June 2014, the Commercial Sector used a total of 998,000 Megawatt hours. Of that, 274,000 Megawatt hours (27.5%) were generated from renewable sources.
    - Commercial, institutional, and residential buildings vary so greatly by usage that it is impossible to generalize an average kilowatt / day consumption rate. (U.S. Energy Information Administration, "Electric Power Monthly," 2014).
    - The Energy Star Program (http://www.energystar.gov/) is a good resource to use to compare a specific building with actual utility data to other buildings.
  - A PV panel might produce 12 watts per square foot of panel. Assuming an average 10 hours of good sunshine per day, that square foot of panel will produce 120 watt hours or .120 kWh per day.
  - Using a residential example where the average house uses 29.85kwh/day, one would need 248.75 sf of panels to produce all the electricity for that average house.
    - Such an array would form a rectangle of about 20' x 13'.
    - For 100 houses an array of 24,875 sf would be necessary, approximately 40' x 622'. On a historic military base with rows of officers' houses or other groupings of residential units, the electricity could be generated by PV panels remotely.

Figure 01 01-5 In a historic district, a good strategy to be used when adding a PV array would be to screen the PV array from the user with landscaping or fencing.

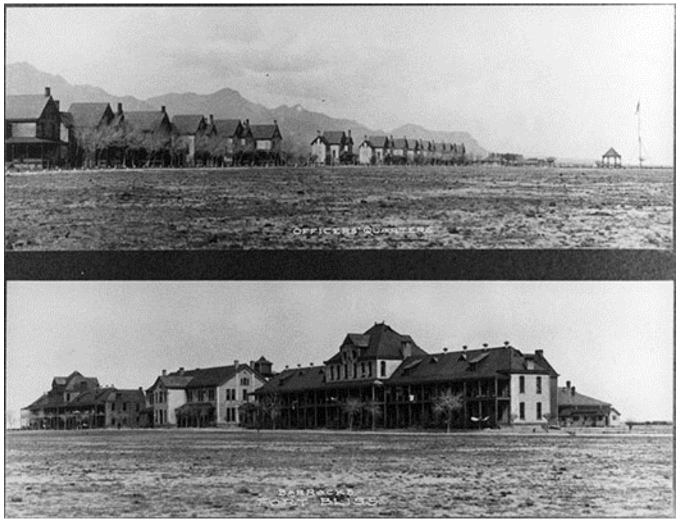


Figure 01 01-6 Ft. Bliss Army Base, El Paso, TX, circa 1895. Officers' quarters at Ft. Bliss are in use today as residences for officers.

CONSIDERATIONS FOR ADDING A PHOTOVOLTAIC PANEL ARRAY IN OR NEAR A HISTORIC DISTRICT continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Step 1: Collect data on the current electrical costs of a historic district or project area.
    - Many military installations are base metered, meaning that there is just one meter for the whole installation. If that is the smallest component that is being metered, it will be necessary to estimate the percentage of electricity use attributed to the project area under consideration for conversion to photovoltaic generation.
    - If no other data is available, the percentage of the area to be converted compared to the percentage of area of the entire installation can be used.
    - See Guideline 26 01 Solar Photovoltaic Panels for an example of how to calculate energy savings and costs. Remember that the example in 26 01 is for a single building, whereas as an array would supply electricity to several buildings in a historic district.
  - Step 2: Determine the cost of electricity in the area to be powered with PV panels. The average electricity price in the Commercial Sector for 1 kWh was 10.94 cents in June 2014, an increase of 2.2% from the previous year. Consider the price comparison map at https://www.pacificpower.net/about/rr/cpc.html
  - Step 3: Determine the potential savings. The amount of energy cost savings that can be expected with the installation of a photovoltaic panel array depends on the project location (the amount of sunlight received), and the cost of electricity services in the area.
    - The website, http://www.trustyguides.com/solar-panels3.html , indicates savings for a 4 kW (DC)/3.1 kW (AC) PV system that is tied to the grid in several US cities. The projected annual savings for this small (by comparison to an array that supports an infrastructure grid) panel is $582.08 in Boston where electricity costs 11.7 cents /kWh and only $395.30 in Chicago where electricity costs 8.4 cents /kWh.
  - Step 4: Determine the cost of PV panels from local vendors.

Resources:

Energy.gov, **"Small Solar Electric Systems,"** July 15, 2012, http://energy.gov/energysaver/articles/small-solar-electric-systems.

CONSIDERATIONS FOR WIND GENERATION IN OR NEAR A HISTORIC DISTRICT:

- **Approach:**
  - Turbines come in several sizes that might apply to Historic Districts or project areas.
  - The higher the tower, the greater the rate of return on wind generation.
    - To raise a 10 kW generator from a 60 foot tower to a 100 foot tower involves a 10% increase in overall system cost, but it can produce 25% more power. (Energy.gov, “Small Wind Electric Systems,” 2012).
  - Wind generation of electric power is most efficient at the scale of large tower wind generators. These large scale installations support generators that use gears to produce electricity at a constant rate, regardless of the wind speed.
  - Wind Turbine Sizes and Applications are classified into 3 different categories for commercial use:
    - **Small Commercial-Scale Onsite Energy Use (10-50 kW)**
      - Produces more power than the average house consumes but can be well suited for small businesses; farms; ranches; facilities such as schools, office buildings, or a part of a campus; or a public load such as a hospital.
      - Typically incorporates a higher level of machine sophistication, resulting in greater efficiency and power production, but also requires more maintenance. However, typically requires less maintenance than larger machines.
      - This class of machine can cost as much as a house.
      - Projects of this size may also trigger the need for onsite resource assessment. These projects can often move forward, however, by using nearby measurements, experienced siting, and project modeling.
      - (U.S. Department of Energy, “What is Wind Power?,” 2014)

General Wind Turbine Sizes		
Scale	Rotor Diameter	Power Rating
Small	3m to 12 m	2kW to 40kW
Medium	12m to 45m	40kW to 999kW
Large	46m and larger	More than 1MW

Chart 01 01-2

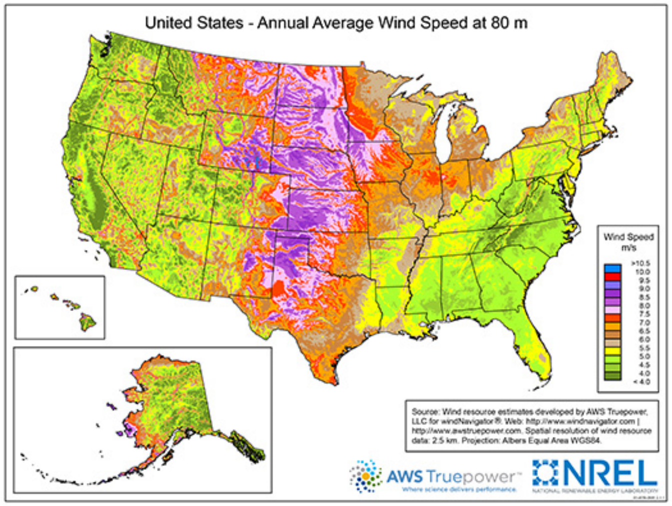


Figure 01 01-7 Map produced by NREL for the U.S. DOE

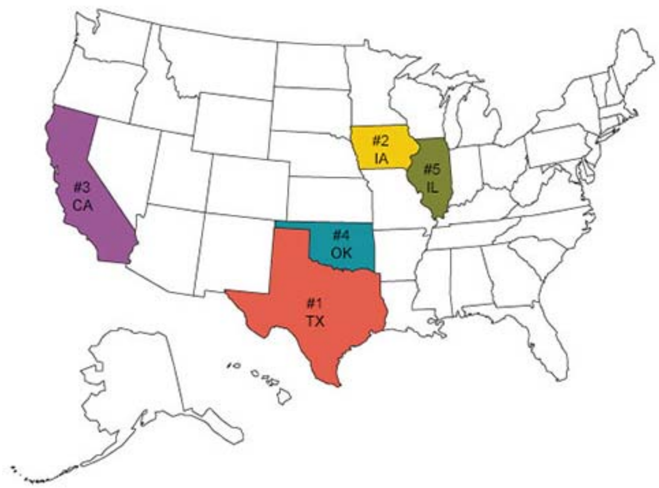


Figure 01 01-8 Top wind power producing states, 2013, by U.S. Energy Information Administration, *Electric Power Monthly,* Table 1.17.B (February 2014).

See Appendices K & L for larger versions of maps.

CONSIDERATIONS FOR WIND GENERATION IN OR NEAR A HISTORIC DISTRICT continued:

- **Approach:**
  - **Commercial Onsite Energy Use (50-250 kW)**
    - Produces commercial quantities of power and can be well matched with campuses, larger facilities, communities, and larger municipal public loads.
    - This wind turbine class shares many technical and operational attributes of utility-scale machines and is often installed on towers that require special permits and coordination with other regulatory organizations or agencies.
    - These turbines often represent a substantial capital investment and thus require corporate or institutional approvals. It is not unusual for facility managers to partner with financial players while developing projects of this size.
    - These projects require experienced and detailed project modeling using onsite or nearby wind resource data.
  - **Large Commercial or Industrial Energy Use (500 kW-1.5 MW)**
    - These systems are the top end of the midsize machines and are well-suited for communities and very large onsite industrial loads. They can even form the basis of small wind farms in certain situations.
    - This machine class is typically indistinguishable from utility-scale turbines on a technology basis. The towers often exceed 200 feet and need to be fitted with obstruction lighting.
    - Projects of this size warrant community involvement and endorsement, or approval at all levels.
    - This class, except in very unusual situations, is typically financed through commercial lenders with their own due-diligence requirements, and therefore, requires feasibility studies and onsite resource assessment campaigns.
  - (U.S. Department of Energy, "What is Wind Power?," 2014)

- **Applicable Secretary of the Interior Standards:**
  - o 5: Distinctive Qualities Preservation

Figure 01 01-9
Large-scale wind turbine

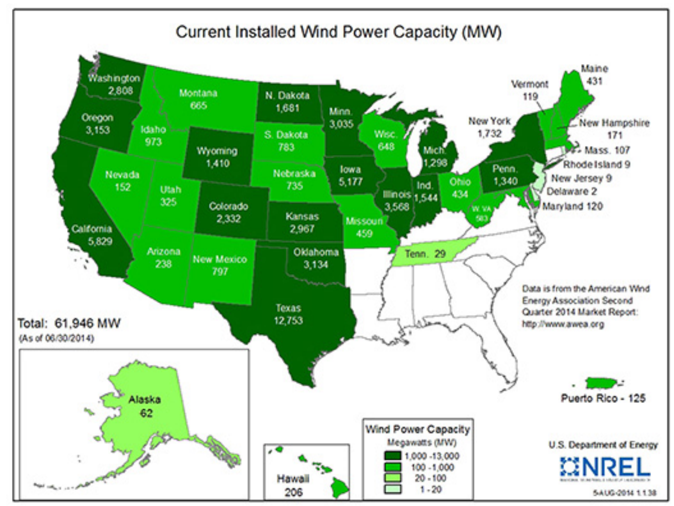


Figure 01 01-10
Map produced by NREL for the U.S. DOE
See Appendix M for larger version of map.

CONSIDERATIONS FOR WIND GENERATION IN OR NEAR A HISTORIC DISTRICT continued:

- **Historic Preservation Effects:**
  - Small wind generators might fit within the context of some historic districts, especially in remote locations that once had wind mills.
  - In other historic districts, the visual impact of large windmills may not be appropriate.
  - The large, most efficient wind generators are too big to be screened.
  - The higher the tower, the more efficient the generation of electric power, but the more objectionable the visual impact on a historic district.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - The U.S. Energy Information Association monitors electrical usage in the US. In June 2014, the Commercial Sector used a total of 998,000 Megawatt hours.
    - Of that, 274,000 Megawatt hours (27.5%) were generated from renewable sources.
    - Commercial buildings vary greatly by usage: retail, financial, data centers, etc. Because of the variation, it is impossible to generalize an average kilowatt / day consumption rate.
    - One must work with the Design Team, and collect actual, onsite data to properly determine the turbine class and the amount of energy generation needed.
  - The Energy Star Program (energystar.gov) is a good resource to use to compare a specific building that has actual utility data with other buildings. Wind energy costs have been reduced from over 55 cents per kilowatt-hour (kWh) in 1980 to under 6 cents/kWh in 2014. (Energy.gov, "Next-Generation Wind Technology," n.d.)
  - The type of turbine class will drastically change the amount of energy generated, and the production and maintenance costs.

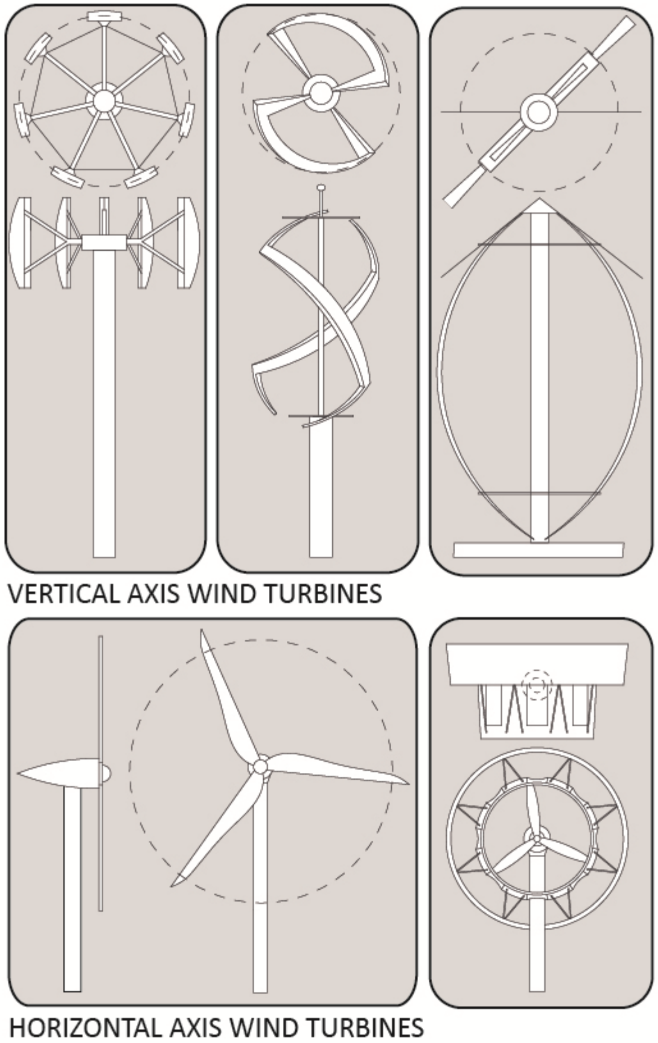


Figure 01 01-11

CONSIDERATIONS FOR WIND GENERATION IN OR NEAR A HISTORIC DISTRICT continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Annual maintenance costs for new turbines are about 1.5%-2% of the original cost.
    - Or $20/kW-yr. (OPPD, “Frequently Asked Questions,” 2006).
  - A turbine cost is approximately $1-$2 million for a 1 MW nameplate capacity installed for commercial classes.
    - The same turbine in 2 MW nameplate capacity would be about $2.8 million

References:

Annual http://www.conserve-energy-future.com/WindEnergyCost.php

Turbine cost http://www.conserve-energy-future.com/WindEnergyCost.php

CONSIDERATIONS FOR USING BIOMASS FOR ENERGY PRODUCTION:

- **Approach:**
  - Biomass refers to organic matter derived from plants and animals. (U.S. Energy Information Administration, "Biomass Explained," 2014)
  - Biomass can be put through different processes to convert it into usable energy. The processes differ depending on the type of biomass that is available. Types of Biomass:
    - Wood
    - Crops
    - Animal Manure
    - Human Sewage
    - Municipal Solid Waste (MSW): contains a large percentage of organic material (food, paper, wood construction waste, etc.). It also contains heavy metals and other materials that are, ideally, removed for recycling prior to energy generation.
  - Energy can be produced from biomass fuel by:
    - Combustion or burning to generate heat and electricity.
      - Typically wood, wood waste or MSW is burned to generate heat and electricity. (U.S. Energy Information Administration, "Biomass Explained," 2014)
      - High pressure steam is also produced and can be used to drive a turbine. (U.S. Department of Energy and FEMP, "Biomass for Electricity Generation," 2011)
      - MSW is burned in waste-to-energy plants, which are becoming more common.
    - Converting into methane gas. Garbage, agricultural, and human waste release methane gas, also referred to as landfill gas or biogas.
      - Has limited usefulness as an energy source within a building or district.
    - Converting into ethanol. Produced by fermentation of crops like corn and sugar.
    - Converting into biodiesel from vegetable oils and animal fats.
  - The use of biomass would only be a viable option where a group of buildings or an installation produces a large volume of organic material to serve as fuel, or in a situation where there were few options for landfills to receive garbage from a community.
  - It is not a viable option for individual buildings on military installations.
  - Island installations or installations in sensitive environmental areas where landfills would not be approved are other candidates for this approach.

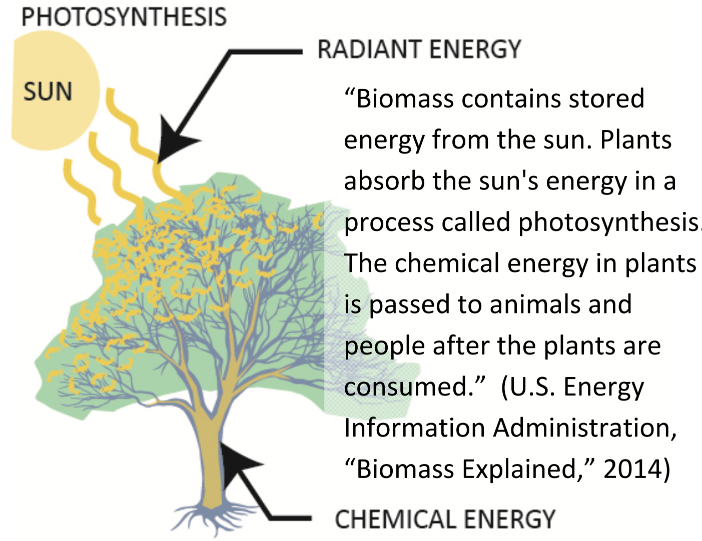


Figure 01 01-12

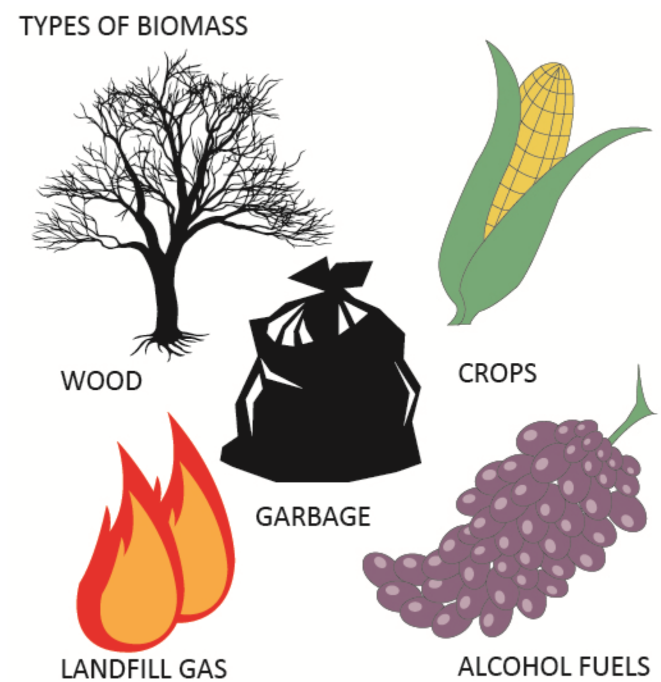


Figure 01 01-13

CONSIDERATIONS FOR USING BIOMASS FOR ENERGY PRODUCTION continued:

- **Approach continued:**
  - There are positive and negative environmental effects.
    - Burning biomass gives off carbon dioxide, similar to other types of fuels.
      - Combustion gases must be "cleaned" prior to release into the atmosphere.
    - It is thought, however, that the CO2 off-gassing produced by biomass is offset by the amount of CO2 absorbed by the organic material throughout its life.
    - There is concern that growing crops, such as corn and sugarcane, to be used solely for the purpose of energy production will cause strain on the agricultural resources necessary for food production.
  - Using certain types of biomass, particularly organic waste and MSW, for energy production provides the added benefit of alleviating some of the strain placed on our landfills by diverting waste generated by the population to energy production facilities.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5:Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
  - 10: Recognizing New Additions

- **Historic Preservation Effects:**
  - The conversion of biomass into usable energy requires a processing facility which could be disruptive to the character of a historic district.
  - Methane gas use is viable and potentially less disruptive, if the historic district is located close to a landfill.
  - A strategy for the production of energy in some historic buildings was the inclusion of a wood burning fireplace. Burning wood to heat a space was an early method of processing biomass to gain energy in the form of heat. If possible, existing wood burning fireplaces should be preserved and used to supplement other heating strategies in historic buildings. See Related Guideline 02 01 Preservation of Historic Energy Related Measures and Devices.

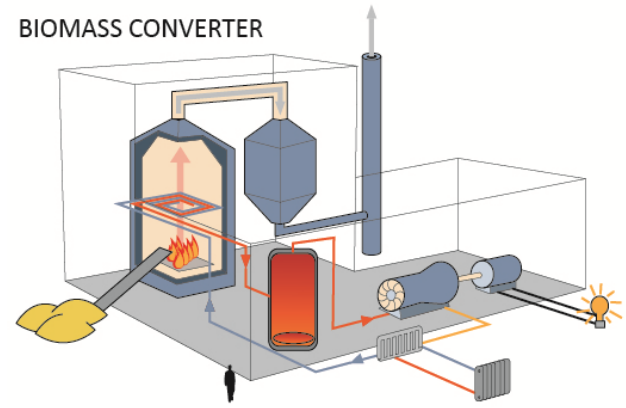


Figure 01 01-14

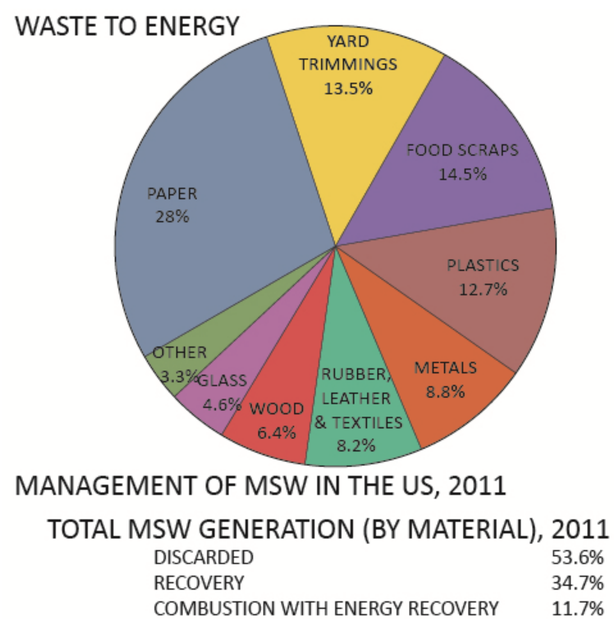


Chart 01 01-3

CONSIDERATIONS FOR USING BIOMASS FOR ENERGY PRODUCTION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - The variety of types of biomass and individual characteristics of each district considering using biomass as an energy source make it difficult to provide actual energy estimations.
  - Using biomass as energy is a viable power source, but is likely not the most efficient power source in a historic district.
  - Using biomass as energy is the most beneficial in a historic district that has a very remote location and in which the power grid is difficult and expensive to maintain. Solar or wind energy would likely be more efficient and cost effective than using biomass.
  - Biomass fuels provided about 5% of the energy used in the United States in 2013.
    - Of that, about 45% was from wood and wood-derived biomass.
    - 44% was from biofuels (mainly ethanol).
    - 11% was from municipal waste. (U.S. Energy Information Administration, "Biomass Explained," 2014).
  - Most types of burned biomass can return electricity to the grid through steam production, and can also help to heat the processing plant where the biomass is burned.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - The use of biomass as energy is very costly.
    - Often, the biomass materials have low and inconsistent energy contents, and in order to convert them into high energy fuels takes money and energy.
  - Additional motivations for using biomass can offset the higher cost. Motivations include:
    - Using biomass for energy benefits the environment in the form of waste diversion.
    - Another motivator would be that there is no place for a land fill.
    - An exceptional amount of waste is generated due to special activities.
  - Other costs associated with the use of biomass for energy production include:
    - Cost of transportation of biomass to the processing facilities.
    - Storage and handling costs of the biomass fuel.

Biomass Energy Process	Cost in Oregon
Combustion w/o cogeneration	5.2-6.7¢/kWh
Gas fired combustion combined cycle	2.8¢/kWh
Landfill gas recovery	2.9-3.6¢/kWh
Anaerobic digestion of animal manure	3.7-5.4¢/kWh
Ethanol production from corn	$1.10/gallon
Ethanol production from agricultural wastes, grasses and wood	$1.15-$1.43/gallon

Chart 01 01-4 "In Oregon, generating electricity from landfill gas is cost-competitive with natural gas power generation…Actual costs would vary depending on financing, location, system design and fuel cost. In the future, new gasification technologies may lower the cost of generating electric power from waste wood and other biomass fuels. In contrast, the estimated cost of generating electricity from a new natural gas-fired, combined-cycle power plant is 2.8 cents per kilowatt-hour." (Oregon.gov, "Biomass Energy").

Federal and State Level Incentives:

See the Database of State Incentives for Renewables & Efficiency: http://dsireusa.org/incentives/index.cfm?EE=0&RE=1&PV=0&ST=0&technology=Biomass&sh=1

See also the U.S. DOE Guide to Integrating Renewable Energy in Federal Construction: http://www2.eere.energy.gov/femp/reconstructionguide/project_funding.html

CONSIDERATIONS FOR CONSERVATION THROUGH WATER SUPPLY AND WASTE WATER STRATEGIES:

- **Approach:**
  - First: refer to the DoD Energy Management Implementation Plan, FY 2007, pages 38-41 for existing water management guidelines. http://www.acq.osd.mil/ie/energy/energymgmt_report/fy06/FY_2007_Implementation_Plan.pdf
  - The conservation of supply water and alternative means of treating waste water can reduce energy use at the district level.
  - These options could be implemented alongside other energy efficiency improvements within a district as a way to improve overall sustainability of the area.
    - Additionally, reducing the consumption of potable water within a district reduces the energy required to bring clean water to a site and treat it once it is used.
  - In some older, historic military installations the waste water (sewer) and the storm water drains were installed to go to the same treatment stations. The common piping of the two was seen as efficient.
    - Contemporary requirements for treatment of sewage are much more stringent than the treatment of storm water, but all the water must be treated to the requirements for sewage.
    - This condition means that reducing storm water and/or sewer water quantities can reduce the energy costs of treatment. The storage of storm water on Green roofs or in retention ponds can also reduce storm water treatment energy costs.
  - Some water conservation strategies for exterior applications:
    - Employ water conserving devices and irrigation controllers. These methods are especially applicable to parks, parade grounds, play fields, etc.:
      - Rain shut-offs: connected to rain sensors and automatically shut off the irrigation system when rain water quantities reach a designated level.
      - Soil moisture sensors: reads the moisture level of the soil and shuts off or delays the irrigation of an area when the soil has sufficient moisture content.
      - Check valves: close irrigation circuits when pressure changes indicating that an irrigation head has burst.

Figure 01 01-15 There are many different types of water harvesting and storage systems. Pictured above is a water-filled building block water storage system.

Reference:
For more information on treatment wetlands see "Guiding Principles for Constructed Treatment Wetlands: Providing for Water Quality and Wildlife Habitat" by the EPA.
http://water.epa.gov/type/wetlands/constructed/upload/guiding-principles.pdf

CONSIDERATIONS FOR CONSERVATION THROUGH WATER SUPPLY AND WASTE WATER STRATEGIES continued:

- **Approach continued:**
  - Some water conservation strategies for exterior applications continued:
    - Use rain barrels or cisterns to harvest rain water on small structures. Retention ponds at larger scales. Retention ponds allow the storm water to soak into the ground, in some areas replenishing the aquifer.
    - Improve paving with the use of permeable pavers to reduce run-off from a site, and increase ground water absorption, which does not require energy to treat it.
    - Revise landscapes with native plants that need little or no irrigation water. Many landscapes need irrigation to become established (2-3 years), then very little water.
    - Constructed Wetlands for Waste Water Treatment: Depending upon the local waste water treatment regulations, soil types, topography and climate, some gray water can be treated by running the water through a specially designed marsh.
  - Some water conservation strategies for interior applications. These means would be especially effective when large groups of buildings are being renovated:
    - Installation of low flow toilets, low flow faucets, and shower heads.
    - In extensive remodels where plumbing is being replaced: Pipe drains from lavatories, sinks, and showers to gray water tanks to use to flush toilets and irrigate.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - Exterior water conservation systems, such as rain barrels or cisterns, need to be underground or screened in order to not detract from the historic character.
  - Review landscape changes with the SHPO in case it is a Cultural Landscape. A compromise would be to have a portion of the property in the original sod or other water consumptive plants and some in new, native planting.

Water-Related Energy Use:
Running the hot water faucet for 5 minutes uses about the same amount of energy as burning a 60-watt bulb for 14 hours.
-U.S. Environmental Protection Agency
Water-related energy use in California also consumes approximately 20 percent of the state's electricity, and 30 percent of the state's non-power plant natural gas (i.e. natural gas not used to produce electricity).
-California Energy Commission

Figure 01 01-16
Historic Landscape at the Bureau of Reclamation in Boulder City, Nevada, originally illustrated how the desert would be converted to a lush landscape. The landscape has recently been partly redesigned using native plants with the SHPO's review and comment.

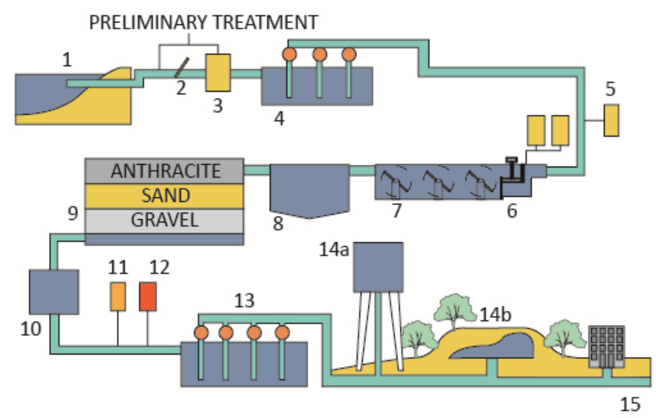
CONSIDERATIONS FOR CONSERVATION THROUGH WATER SUPPLY AND WASTE WATER STRATEGIES continued:

- **Historic Preservation Effects continued:**
  - The original plumbing fixtures may be character defining features and need to be refitted instead of replaced.

- **Energy Savings Potential:**
  - Using less water reduces energy consumption by saving on the energy required to move water from source to treatment plant, clean water, and bring it to a site.
    - Education programs on water conservation may be the least cost approach to water and energy conservation.
  - If the military installation is connected to the public water utilities, the reduction of energy use through water conservation will not be realized in the installations' water bill directly, but savings will be recognized in the water utility bill. Any energy costs for pumping on the military installation will show a reduction in the energy bill.
  - Projecting the energy savings of a water conservation program is not possible in this Guideline given the wide variety of circumstances and variables involved.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - First Step: Collect basic data on the current water costs of a historic district, or a larger area that contains a historic district.
    - If the installation is base metered, then it will be necessary to estimate the percentage of water use attributed to the historic district or project area under consideration for the water conservation program. If no other data is available, the percentage of the area to be converted compared to the percentage of area of the entire installation can be used.
  - Due to the variables from location to location, projecting cost savings produced by water conservation is not reliable at this large scale. Specific cost savings can be determined by reviewing the water utility billings to identify the cost per gallon usage. As various conservation measures are put in place, the water usage can be monitored over a period of time. Since water usage is often seasonal and summer use is frequently higher, the time period for monitoring savings should not be less than a year.

WATER TREATMENT PROCESS



1. INTAKE PIPE AT THE SOURCE
2. PROTECTIVE BAR SCREEN
3. TRAVELING WATER SCREEN
4. LOW LIFT PUMP WELL
5. PRE-CHLORINATION
6. COAGULATION
7. FLOCCULATION
8. SEDIMENTATION BASIN
9. SAND FILTRATION
10. CLEAR WELL
11. POST CHLORINATION
12. FLUORIDATION
13. HIGH LIFT PUMP WELL

14a. ELEVATED WATER STORAGE TOWER
14b. GROUND LEVEL RESERVOIR
15. TO DISTRIBUTION SYSTEM

Figure 01 01-17

GUIDELINE DESCRIPTION: Different building types use energy differently**.** Some military historic districts have several different types of buildings: offices, food services, commissaries, schools, residences, etc. Budgets may not allow for energy up-grades in all the buildings. Which types will reduce energy costs the most, if upgraded? This Guideline examines the energy use characteristics of building types commonly found on historic military installations, and discusses which types are likely to most greatly reduce energy use if improvements are made.

This Guideline looks at building energy improvement at the planning scale. It is intended to help planners decide where to start improving the overall energy use of a historic military installation. Once a particular building type is selected for rehabilitation, the other Guidelines in this report can assist with determining the more specific cost benefits of improvements to that particular building type.

The information provided in this Guideline are ideas; it is up to the Planning Team to ensure that the specific implementation meets UFC requirements.

RELATED GUIDELINES:

- 00 01 Project Organization
- 00 02 Working with State historic Preservation Officer (SHPO)
- 00 03 Major Preservation and Energy Issues.
- 01 01 Infrastructure Energy Preservation in Historic Districts

GENERAL NOTES:

- Standards for thermal comfort and adequate lighting have become more stringent since most historic districts were constructed. However, some buildings built during the later 1950s and 1960s are becoming eligible for the NRHP. Many of these buildings were designed to rely heavily on energy consumptive HVAC and lighting. Planners should become familiar with the age of the historic resources on the military installation.
  - See the U.S. Energy Information Administration websites for consumption for buildings by year built, http://www.eia.gov.

Figure 01 02-1
Aerial photograph of Wright Patterson Air Force Base, Dayton, OH, demonstrates the variety of building types encountered on one military base.

Figure 01 02-2
Aerial photograph of Oakland Army Base, CA, 1950. Military bases contain many building types, including retail, office, housing, education, and military.

GENERAL NOTES continued:

- Buildings that were built in the 1970's used the most energy (Btu/ft2) of any period from 1920's through the present.
- Buildings from the 1960's are starting to become eligible for historic status. It is still important to preserve these buildings as part of our history while reducing their energy use.

- Early in the process of beginning to plan for energy improvements to historic districts, determine with the CRM/SHPO the typical character defining features of the district to be preserved. Review with the CRM/SHPO the list of buildings and features that are Contributing and Non-Contributing.

CONSIDERATIONS FOR PLANNING HISTORIC REHABILITATION PROJECTS BY BUILDING TYPES:

- **General:**
  - Many military installations meter their energy at a central point making the current and future energy use of individual buildings difficult to determine directly. Therefore, data obtained from the civilian sector may be used as surrogate information on various building types.

- **Approach:**
  - Develop the inventory of building types in the historic district. The Nomination Form for the Historic District may include an inventory of buildings. That inventory may be arranged by building types.
  - If possible, obtain information on the total square footage by building type. This information can help determine which type is using the most energy on a specific installation.
  - Analyze the inventory with the information about building types in this Guideline to establish which building type(s) have the greatest energy saving potential. Concentrate on the rehabilitation of that type(s).
  - If certain buildings are slated for remodeling with funds already in place, presumably, those buildings will become the highest priority for energy improvements.

Figure 01 02-3 Ft. Bliss, El Paso, TX. The historic barracks have been converted to offices.

Figure 01 02-4 Santa Ana Naval Air Station / Marine Corps Air Station, Tustin, CA. Historic blimp hangars.

Figure 01 02-5 Los Angeles Air Force Base, El Segundo, CA. Commissary Building.

CONSIDERATIONS FOR PLANNING HISTORIC REHABILITATION PROJECTS BY BUILDING TYPES continued:

- **Approach continued:**
  - Conduct an energy audit (see Guideline 00 01 Project Organization) of a sample of the building type selected to establish a base line of energy use. This base line will be helpful to determine the energy use reduction after improvements, especially if the building is not separately metered. For a good description of the levels of Energy Audits, see Section 2.4 Energy Audits in *Advanced Energy Retrofit Guide for Office Buildings,* (Pacific Northwest National Laboratory, PECI, and U.S. Department of Energy 2011).

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - See Guideline 01 01 Infrastructure Energy Preservation in Historic Districts for suggestions on improving energy efficiency to entire historic districts. When energy generations with PV panels or wind generators are proposed, consider installations outside district boundaries to avoid adverse visual impacts on the historic district.
  - Once the building(s) that uses the most energy, or has the most energy savings potential is selected, review all the other Guidelines in this report for ways to conserve energy. Groups of similar buildings can all be improved at once if funds are available.

Figure 01 02-6 Fort Des Moines Provisional Army Officer Training School, IA; built in 1917. Today, this building functions as the Fort Des Moines Museum and Education Center.

Figure 01 02-7 Atterbury Army Air Field, Columbus, IN. Shop Field Maintenance Building.

CONSIDERATIONS FOR PLANNING HISTORIC REHABILITATION PROJECTS BY BUILDING TYPES continued:

- **Energy Savings Potential continued:**
  - Unlike many of the other Guidelines in this report, this Guideline will not deliver a specific Energy Savings Potential. It is intended to assist with decisions about which types of buildings should be renovated to save energy. One major resource, "Realizing the Energy Efficiency Potential of Small Buildings," http://www.preservationnation.org/information-center/sustainable-communities/green-lab/small-buildings/ reports that in the civilian sector, "small commercial buildings….could reduce total energy consumption in the overall commercial sector by as much as 17 percent using current (2013) cost effective technology." (National Trust for Historic Preservation, Preservation Green Lab, and New Buildings Institute, "Realizing the Energy Efficiency," 2013).
  - Building Types"
    - Residential:
      - In the private sector and in many military installation historic districts, single-family residences are the most prevalent building type and are responsible for the largest portion of energy consumed in community settings.
      - For residences, some energy saving improvements may not involve building improvements. Replacement of heating and cooling units and household appliances (water heaters, dishwashers, refrigerators, clothes washers and dryers) may be the most cost effective option to take. Possibilities for these replacements may depend upon funding categories available. Building improvements are often made with capital improvement budgets and appliance replacements may be purchased with maintenance budgets.

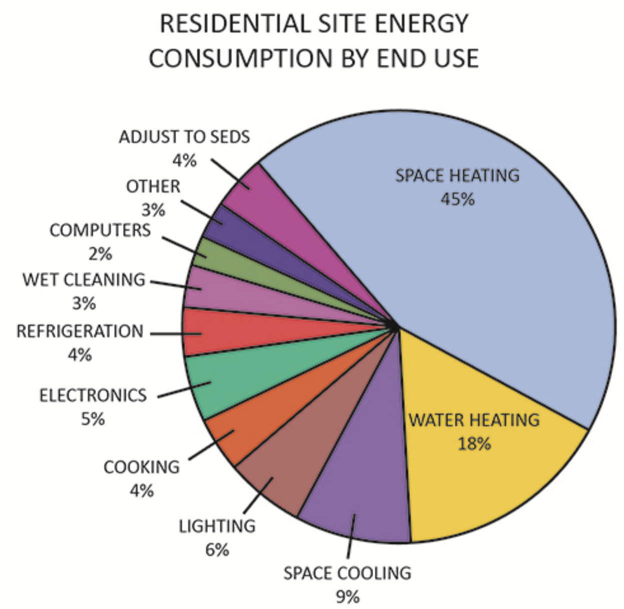


Chart 01 02-1

CONSIDERATIONS FOR PLANNING HISTORIC REHABILITATION PROJECTS BY BUILDING TYPES continued:

- **Energy Savings Potential continued:**
    - Chart 01 02-1 describes how energy is used in Residential Buildings. It groups single and multi-family housing together. The chart indicates that Space Heating and Water Heating are the largest users of energy. Therefore, multiple building residential projects that reduced these heating costs would have the greatest impact. Space heating costs can be reduced with improved insulation (Guidelines 03 31, 04 21, 05 51, 06 81, 07 01, 07 21, 07 31, 07 51), increasing window efficiency (Guidelines 08 01 and 08 52), reducing infiltration (Guideline 08 41) and replacing heating units (Guidelines 23 08, 23 11, 23 12, 23 21, 23 22, 23 23, 23 40). Water Heating improvements are discussed in Guideline 22 33 Hot Water Energy Conservation.
  - The Guidelines noted in the paragraph above indicate the Energy Savings Potential of individual projects. These discussions can produce a general idea of energy savings for multiple building project improvements for housing in a specific military historic district.
  - Note: Other sources differ in the percentages assigned to various end uses. In those sources, Space Heating is still the largest user. Space Cooling and Water Heating may be switched in their order. These discrepancies illustrate that the data is difficult to compile, vary by climate and circumstances of the buildings, etc. However, there seems to be agreement that Space Heating, Water Heating and Space Cooling are the three biggest users of energy in residential units.
  - Non-Residential Buildings (aka “Commercial”)
    - Energy use data on Non-Residential Buildings is typically called “Commercial” energy use in the private sector. The following chart indicates energy use in Thousand Btu/sf for 14 categories of building use, including vacant buildings. For vacant buildings it is assumed that they are heated to prevent freezing of water pipes, and therefore use energy.

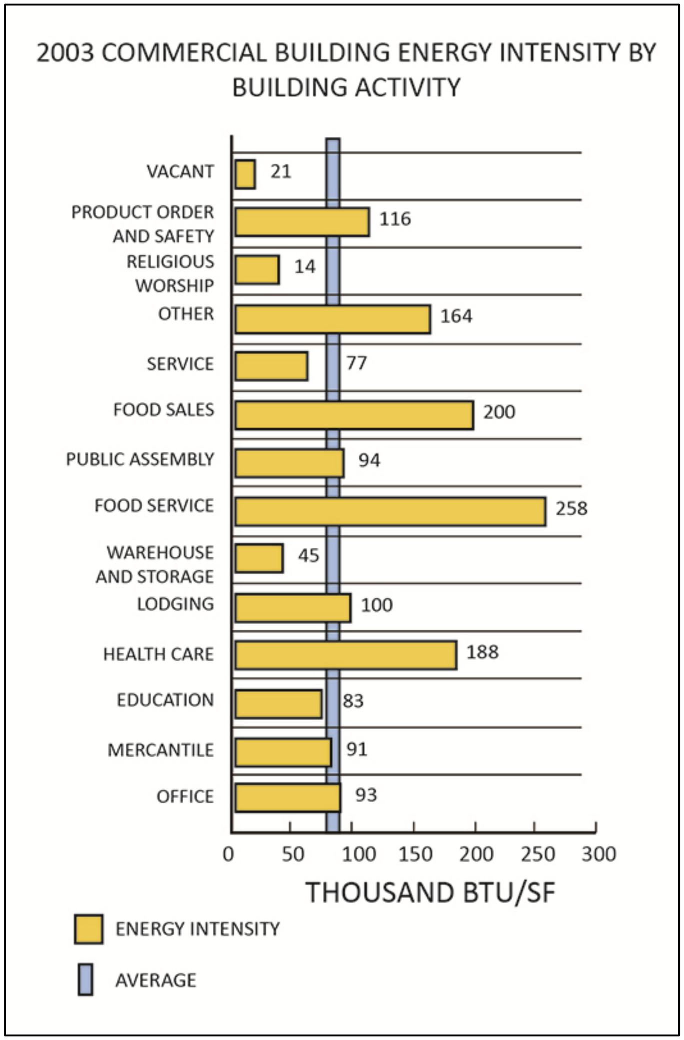


Chart 01 02-2

CONSIDERATIONS FOR PLANNING HISTORIC REHABILITATION PROJECTS BY BUILDING TYPES continued:

- **Energy Savings Potential continued:**
    - Chart 01 02-2 shows that the three biggest energy using building types are Food Service, Health Care, and Food Sales. That data implies that those three building types are the most likely building types to improve from an energy use stand point. Conversely, there is the implication that improvements to Vacant Buildings and Warehouses will not save great amounts of energy. That inference may be true, but the reality depends upon the specifics of those individual buildings at a specific military installation, in specific climates, using a specific type of fuel, and the physical realities of their construction.
    - Offices: Energy use in offices is divided up as shown in Chart 01 02-6:
        - Charts 01 02-3, 4, and 5 indicate that the largest energy users in office buildings are heating, lighting, and cooling. The source of this chart discusses the various aspects of these factors and recommends measures to improve energy use in five different climate zones. It also discusses the value of addressing Operations and Management measures as the least costly approach. These measures involve improving maintenance and controls and other low cost activities that improve the efficiency of existing systems.
    - Schools
    - Retail/Commissaries
        - “Significant savings can often be achieved with minimal risk and capital outlay by improving building operations and restructuring maintenance procedures. A study by Lawrence Berkeley National Laboratory indicated that approximately 12% energy savings could be achieved in a typical grocery store with a payback period of .3 years. Savings well in excess of 305 can be achievable if a store has particularly severe O&M weaknesses. (National Renewable Energy Laboratory et al., “Grocery Stores,” 2013).
    - Food Service
    - Health Facilities
    - Warehouse/Industrial

Energy Use in Offices	
Building System	**Percent of Energy Use**
Heating	35%
Lighting	25%
Cooling	10%
Other	10%
Ventilation	6%
Computers	6%
Office Equipment	3%
Refrigeration	3%
Water Heating	2%

Chart 01 02-3

Electricity Use	
Building System	**Percent of Energy Use**
Refrigeration	60%
Lighting	18%
HVAC	15%
Other	4%
Water Heating	2%
Food Preparation	6%

Chart 01 02-4

Gas Use	
Building System	**Percent of Energy Use**
Space Heating	56%
Water Heating	22%
Food Preparation	16%
Other	4%

Chart 01 02-5

CONSIDERATIONS FOR PLANNING HISTORIC REHABILITATION PROJECTS BY BUILDING TYPES continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Because this portion of the Guidelines deals with energy conservation at the planning scale, we cannot be specific about a particular direction for the reader to take. However, if the energy conservation effort is to deal with a historic district, one should consider the following steps:
    - Determine the different building types in the district.
    - Review Chart 01 02-2 in this section to determine which of the building types present use the most energy.
    - Review the other charts in the section to determine where in that building type the energy may be spent.
    - If funds are limited, direct improvement budgets to the building type and energy use within that building.
  - For example Chart 01 02-2, indicates that food service uses more energy than other building types. If there are mess halls or officers clubs in the historic district, the remaining charts indicate that funds should be spent on new, more efficient refrigeration and space heating.

Sources:

National Trust for Historic Preservation, Preservation Green Lab, and New Buildings Institute, **"Realizing the Energy Efficiency Potential of Small Buildings"** (National Trust for Historic Preservation, June 2013).

This report addresses commercial building types such as offices and retail establishments including food service. Much of the research can be applied to Owner Operated buildings such as those on military installations.

U.S. Department of Energy, **"Buildings Energy Data Book,"** March 2012, http://buildingsdatabook.eere.energy.gov/ChapterIntro3.aspx.

Pacific Northwest National Laboratory, PECI, and U.S. Department of Energy, **"Advanced Energy Retrofit Guide for Office Buildings: Practical Way to Improve Energy Performance"** (U.S. Department of Energy, September 2011).

National Renewable Energy Laboratory et al., **"Advanced Energy Retrofit Guide for Grocery Stores: Practical Ways to Improve Energy Performance"** (U.S. Department of Energy, July 2013).

GUIDELINE DESCRIPTION: This Guideline will examine energy related measures and devices that are commonly found in historic structures prior to the 1950s, and were usually used for heating, ventilation, or shading. Lighting is not covered in this Guideline, but is discussed in related Guidelines. This Guideline will discuss how and why these measures and devices were used and provide considerations regarding their protection during construction, continued use, modification, and preservation. The information provided in this Guideline are ideas; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

Figure 02 01-1 Ventilating

The historical energy related measures and devices considered here fall into three categories: heating, ventilation, and shading. Heating methods and devices include fireplaces, stoves, boilers, and sun rooms. Ventilation methods and devices include operable windows placed for cross ventilation, transoms at doors and windows, undercut doors, and attic louvers. Shading measures include window awnings. Porches and deciduous trees which are also shading devices are covered in Guideline 32 29 Preservation of Historic Plant Materials for Shading and Wind Reduction.

Determining Energy Cost Considerations for this Guideline is not realistically possible because the initial energy use of the devices and measures is not knowable for comparison, and the variables of reuse of these devices and measures are excessively broad. For these reasons, energy use will be discussed in general terms for each component.

Figure 02 01-2 Shading

RELATED GUIDELINES:

- 00 02 Working with State Historic Preservation Officer (SHPO)
- 00 03 Major Preservation and Energy Issues.
- 08 01 Increasing Energy Efficiency in Historic Windows
- 08 02 Natural Lighting
- 08 41 Reducing Air Transfer at Historic Doors/Entrances
- 12 22 Insulative Curtains, Drapes, and Window Films
- 23 08 Selecting HVAC Systems
- 32 29 Preservation of Historic Plant Materials for Shading and Wind Reduction

GENERAL NOTES:

- Standards for thermal comfort and adequate lighting have become more stringent since most historic buildings were constructed. However, some buildings built during the later 1950s and 1960s are becoming eligible for the NRHP. Many of these buildings were designed to rely heavily on energy consumptive HVAC and lighting. This Guideline looks at measures and devices prior to the advent of mechanical cooling.
- Some of the items discussed in this Guideline are not really energy saving devices. They are rather measures or devices that were used to provide thermal comfort and required substantially less energy than their modern day corollary.
- On all historic energy related measures and devices, determine with the CRM/SHPO, early in the process, which ones are considered character defining features, and which can be removed or altered significantly.
- Some energy related devices, such as windows that can take advantage of cross ventilation during that part of the year when mechanical cooling is not yet required, can continue to operate according to their original design in a very energy efficient way. Management support may be required.
- Energy related devices that are determined to be character defining features to remain should be protected during construction. They can be protected with wooden barriers, or tenting, or can be crated, removed to storage, refurbished, and returned to the building when construction is complete.
- With permission of the CRM, and with comment from the SHPO, energy related devices need not be used in their original mode. They can function as historic artifacts.
- In historic industrial buildings, such as a blacksmith's shop at a cavalry base, other energy related devices may be designated character defining features. Such equipment is not covered in this Guideline, but is often refurbished and retained as an exhibit feature.

Figure 02 01-3 Transom windows aid in cross-ventilation.

Figure 02 01-4

CONSIDERATIONS FOR USING HISTORIC WOOD BURNING FIREPLACES:

- **Approach:**
  - Determine if the fireplace is a character defining feature to be retained. If so, this Guideline will be applicable.
  - If the building interior is historically significant, careful collaboration with the CRM/SHPO is needed to find acceptable solutions for all concerned parties.
  - Historic materials associated with the fireplace must be protected during construction.
  - <u>Reuse as an operating fireplace</u>
    - Fireplaces have the inherent problem that when the fire goes out late in the evening, the heated room air will naturally travel up the chimney.
    - With the review and comment of the SHPO, a set of glass doors can be installed to reduce heat loss up the chimney when the fire dies. In these cases, it may be possible to add an outside air inlet to avoid using heated room air to provide oxygen for the fire.
    - On some occasions, the hearth and mantle are the important features and a new, closed box wood burning stove can be inserted in the firebox. These closable stoves are more energy efficient than a fireplace with glass doors.
  - <u>Cease operation of fireplace and retain as a character defining feature.</u>
    - The flue should be permanently closed to prevent the escape of heated air up the chimney.
    - Existing chimney chases that are no longer used for that purpose may sometimes be used for running electrical conduit, HVAC ducts (if of sufficient size), and other new vertical, utility components.
    - The top of the chimney should be capped unobtrusively and weather sealed.
    - The unused fire box may be adorned with decorative arrangements, historic andirons, or other removable features.

Figure 02 01-5 Before **Figure 02 01-6** After
Wood burning fireplace at Ft. Stanton, NM. Use as an active fireplace was discontinued.

Figure 02 01-7 Wood burning fireplace in barracks at Ft. Bliss, TX.

CONSIDERATIONS FOR USING HISTORIC WOOD BURNING FIREPLACES continued:

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Often, a strategy for the production of energy in historic buildings was to include a wood burning fireplace. Burning wood to heat a space was an early method of processing biomass to gain energy in the form of heat. If possible, existing wood burning fireplaces should be preserved and used to supplement other heating strategies in historic buildings. See related Guideline 01 01 Infrastructure Energy Preservation in Historic Districts.
  - Wood burning fireplaces often have hearths, mantles, and accessories that are important character defining features.
  - The removal of a fireplace, mantle or hearth may be an adverse effect on the aesthetics of a room. Discontinuing its use and providing repairs as required are more acceptable.
  - Preservation of a fireplace during construction might include erecting a wooden protection structure around the fireplace to prevent damage from other activities during construction.

- **Energy Savings Potential:** As described above in General Notes, this Guideline does not attempt to calculate the energy savings on the features discussed. It does offer some general energy savings information for consideration.
  - A wood-burning fireplace will provide heat while in use, but it is not particularly efficient, and involves considerable maintenance. Firewood and kindling must be stocked, ash removed, and cleaning of the hearth and flue are all maintenance issues. When the real wood-burning fireplace adds great ambience to the room, these efforts are considered worth the effort.

Figure 02 01-8 Before **Figure 02 01-9** After
Wood burning fireplace at Ft. Stanton, NM. Use as an active fireplace was discontinued.

Figure 02 01-10
Glass door covering fireplace.

CONSIDERATIONS FOR USING HISTORIC WOOD BURNING FIREPLACES continued:

- **Energy Savings Potential continued:**
  - The major energy saving strategy is to prevent the warm room air from escaping up the chimney when the fire is out. This savings can be accomplished by closing the damper immediately after the fire is out, or with SHPO review and comment, adding glass doors that can be closed while the fire is going. Assigning a person to close the damper is an administrative issue.
  - Air infiltration is a substantial energy loss. Several Guidelines address issues of air infiltration: See Guideline 07 92 Using New Joint Sealants on Historic Components; Guideline 08 41 Reducing Air Transfer at Historic Doors/Entrances; Guideline 08 01 Increasing Energy Efficiency in Historic Windows

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Since quantitative information on energy saving potential is not available for individual circumstances, there are no corresponding Cost Considerations. The Guideline sections noted in the section above can give some guidance on how much can be saved by reducing infiltration.

Energy Loss due to Air Infiltration:

According to the U.S. Department of Energy, about 50% of the average fuel bill is the result of heat loss from air infiltration.

CONSIDERATIONS FOR USING HISTORIC WOOD AND COAL BURNING STOVES:

- **Approach:**
  - Determine if the stove is a character defining feature. If so, this Guideline will be applicable.
  - If the building interior is historically significant, careful collaboration with the CRM/SHPO is required to find acceptable solutions for all concerned parties.
  - Wood and coal burning stoves were often located near a wall, but in large, open spaces such as barracks, they were sometimes located in the center of the room. When discussing the importance of the stove with the CRM/SHPO, also discuss the importance of the location. Can the stove be retained as an artifact, but moved if necessary for the future functioning of the space?
  - If the stove is to be retained, either as a functioning stove or a historic artifact, it must be cleaned and protected during construction. Depending on its size and the nature of the work to be done in the room, it may need to be crated and put into storage during construction.
  - Reuse as an operating stove
    - Stoves are not as open as fireplaces, but still have the inherent problem that when the fire goes out late in the evening, the heat of the room can travel up the chimney. Stoves are not as bad as fireplaces in this regard because the openings are much smaller.
    - Both wood and coal burning stoves are inherently messy, with coal being messier than wood and harder to clean because of the coal dust. For this reason, it is rare to see a coal burning stove reused for heating.
  - Cease operation of stove and retain as a character defining feature or Exhibit
    - The flue should be permanently closed to prevent the escape of heated air up the chimney.
    - Wood and coal burning stoves are often decommissioned, cleaned, and retained as historic artifacts, assuming the new room uses allow for it.

Figure 02 01-11
Historic wood burning stove.

CONSIDERATIONS FOR USING HISTORIC WOOD AND COAL BURNING STOVES continued:

- **Approach continued:**
    - Existing chimney chases engaged in walls that are no longer used may sometimes be used for running electrical conduit, HVAC ducts (if of sufficient size), and other new vertical, utility components.
    - The top of the chimney should be capped unobtrusively and weather sealed. If the chimney is an insignificant metal cylinder, it may not be considered important enough to retain.

- **Applicable Secretary of the Interior Standards:**
    - 2: Historic Character Preservation
    - 5: Distinctive Qualities Preservation
    - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
    - The nature of the original use of the room that the stove heated, and the proposed use will be important factors in the decision to retain the stove, functioning or not.
    - Refurbishing a historic stove, even if it is not to be used for heating, can add to the historic character of a room.
    - Free-standing stoves are often removed from historic buildings, leaving only a circular metal cover over the hole where the stove pipe entered a chimney. If this is the case, discuss with the SHPO if it is recommended that the cover should be preserved.
    - If the stove is missing and the chimney is not considered Character Defining, the chimney can be removed or reused for another purpose.

- **Energy Savings Potential:** As described above in General Notes, this Guideline does not attempt to calculate the energy savings on the features discussed. It does offer some general energy savings information for consideration.
    - A wood or coal burning stove will provide heat while in use, but it is not particularly efficient, and involves considerable maintenance. Firewood and kindling or coal must be stocked, ash removed, and cleaning of the hearth are all maintenance issues.

Figure 02 01-12 Historic chimney caps.

Figure 02 01-13 Chimney at Ft. Stanton, NM.

CONSIDERATIONS FOR USING HISTORIC WOOD AND COAL BURNING STOVES continued:

- **Energy Savings Potential continued:**
    - When the real wood or coal burning stove adds great ambience to the room, these efforts may be considered worth the effort.
  - The major energy saving strategy is to prevent the warm room air from escaping up the chimney when the fire is out. These savings can be accomplished by closing the damper immediately after the fire is out. Assigning a person to close the damper is really not a practical solution. No one will want to wait for the fire to die, nor put it out with water.
  - Air infiltration is a substantial energy loss. Several Guidelines address issues of air infiltration: See Guideline 07 92 Using New Joint Sealants on Historic Components; Guideline 08 41 Reducing Air Transfer at Historic Doors/Entrances; Guideline 08 01 Increasing Energy Efficiency in Historic Windows

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Since quantitative information on energy saving potential is not available for individual circumstances, there are no corresponding Cost Considerations. The Guidelines noted in the section above may give some guidance on how much can be saved by reducing infiltration.

Figure 02 01-14 Wood burning stove heating grocery, Detroit, ca. 1922.

CONSIDERATIONS FOR USING HISTORIC CENTRAL BOILERS AND RADIATORS:

- **Approach:**
  - The case of a central boiler being a character defining feature of a historic building would be rare, indeed. However, depending on the history of the equipment, such as a "first of its kind" situation, there may be times when the equipment should be saved.
  - In some cases, when a hot water heating system is reused with a new boiler, the radiators within the rooms served by the boiler, are refurbished and reused as radiators. However, exposed hot surfaces are commonly considered a hazard, and the reuse of radiators as heating elements is now rare.
  - More commonly, the radiators within the rooms served by the boiler are decommissioned and retained as historic artifacts. This retention may especially occur if the radiators have decorated castings.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Given that boilers are rarely considered character defining features, the room radiators are more commonly the items to be refurbished and retained as historic artifacts.
  - In industrial buildings where the boiler or other heat producing equipment is an important part of the history of the building but is not intended to be reused, they can be cleaned and exhibited with interpretive signs.
  - Historic radiators, as described above, may be considered a hazard because they are hot to the touch, making their use rare. If the historic application was covered by a cabinet unit of some type, the hazard issue is solved.
  - Historic heat registers (or grilles) were often decorated and treated as artifacts. They should be retained, and in some cases can continue to serve as registers.

Figure 02 01-15 Decorative radiator cover, from the abandoned De Anza Motor Lodge in Albuquerque, NM, built in 1939.

Figure 02 01-16 Decorative radiator cover at Coronado Elementary School, Albuquerque, NM

CONSIDERATIONS FOR USING HISTORIC CENTRAL BOILERS AND RADIATORS continued:

- **Energy Savings Potential:**
  - As described above in General Notes, this Guideline does not attempt to calculate the energy savings on the features discussed. It does offer some general energy savings information for consideration.
  - Contemporary boilers are much more energy efficient than historic ones. How much more efficient depends on the original boiler and the replacement. New boilers are also much smaller for a given output. See Guideline 23 08 Selecting HVAC Systems for more information.
  - The heating efficiency of historic radiators varies widely with the amount of insulation on the pipes to the radiator, the distance from the boiler, the configuration of the fins, and other factors.
  - The heat distribution is greatest near the radiator, leaving cold spots in the room. Contemporary heating systems are designed for more even distribution, and therefore are generally more comfortable.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Since quantitative information on energy saving potential is not available for individual circumstances, there are no corresponding Cost Considerations presented here.

Figure 02 01-17 Radiator at Ft. Stanton

Figure 02 01-18 Decorative Historic Radiator

CONSIDERATIONS FOR HISTORIC SUN ROOMS:

- **Approach:**
  - Sun Rooms, glazed enclosures, usually facing south in the northern hemisphere and north in the southern hemisphere, were popular in areas where long winters forced people indoors for long periods of time. On sunny days, the heat from the Sun Room, developed by the "Greenhouse Effect," could be shared by the adjacent rooms.
  - The "Greenhouse Effect" is caused by the fact that glass is transparent to the sun's energy that arrives at a very high frequency. The sun's energy heats surfaces in the Sun Room, and these surfaces re-radiate heat, but at a much lower frequency. The glass is opaque to the lower frequencies, and traps the heat energy inside.
  - Sun Rooms were used at military installations usually in residential or recreational facilities. They were also used at installations caring for veterans with tuberculosis, such as Ft. Bayard, New Mexico, when "the sun cure" was the major therapy.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - In some cases, Sun Rooms have been enclosed with solid walls to provide all weather space and night time use. Ideally for preservation, these enclosures should be returned to their original configuration. However, need for space and high costs often discourage restoration of ample glazing.
  - In Sun Rooms that have single pane glazing or are having glazing restored, double or even triple paned glass can be installed, with SHPO review and comment. New glass types available today include those that admit more solar energy than they release at night. The detailing of the window frame will need to be studied to determine how to accommodate the additional thickness of the new glass and preserve the original appearance.
  - Historic Sun Rooms can be provided with unobtrusive ducting that transfers heat, by use of exhaust fans, to other parts of the building. This transfer reduces overheating in the sunroom, and reduces heating costs for the rest of the building.

GREENHOUSE EFFECT

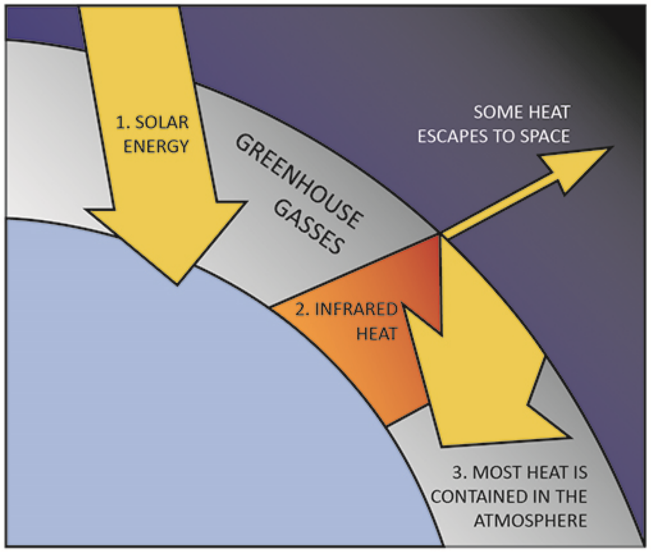


Figure 02 01-19

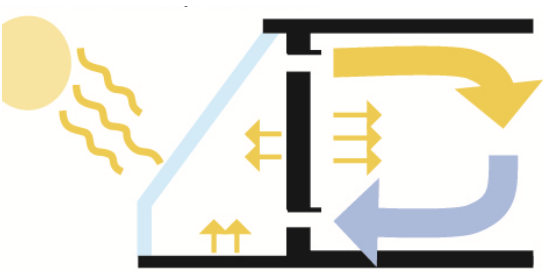


Figure 02 01-20 Air circulation diagram in a passively conditioned space with attached sun room.

CONSIDERATIONS FOR HISTORIC SUN ROOMS continued:

- **Energy Savings Potential:**
  - As described above in General Notes, this Guideline does not attempt to calculate the energy savings on the features discussed. It does offer some general energy savings information for consideration.
  - Sun Rooms can be equipped with insulative curtains that are drawn at night. That energy savings effort would have to be assigned to an individual, or have the Sun Room equipped with curtains operated on a thermostat.
  - As noted above, transferring the excess heat from the Sun Room during winter days can reduce the energy use of the remainder of the building.
  - Depending upon the orientation of the Sun Room and the amount of shading provided from nearby trees, Sun Rooms can overheat in the summer. Shading screens can be placed over the roof (and removed in winter), and ventilating fans can be unobtrusively installed to exhaust the room air to the outside in the summer.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Since quantitative information on energy saving potential is not available for individual circumstances, there are no corresponding Cost Considerations.

Figure 02 01-21 Residential Sun Room.

Figure 02 01-22 Commercial Building with glass dome, acting like a sun room.

CONSIDERATIONS FOR HISTORIC HIGH CEILINGS:

- **Approach:**
  - Before powered air conditioning was accepted, rooms were designed with higher ceilings than they are today. The reason for this additional volume was to allow the hot air to accumulate higher up, away from the room's occupants.
  - As electricity became available, many buildings incorporated ceiling fans to produce air movement in the room and have that "breeze" cool the occupants. The higher ceilings allowed for ceiling fans to operate above people's heads without problems.
  - The high ceilings also added the aesthetic component of grace to the proportions of the rooms; making them feel less cramped than rooms of the same horizontal dimensions, but with lower ceilings.
  - In many historic buildings, the high ceiling has been seen as providing an opportunity to add HVAC ducts to the room and cover them with a lower, new ceiling. Sometimes this change was done with disregard for the windows in the adjacent walls. Often the whole room ceiling was lowered, even though only a portion of the ceiling area was occupied with HVAC ducts.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - The height of the ceiling of a room is an important feature of the room. HVAC ducting, if it has to be present, should be restricted to the edge of the room, furred out with concealing material.
  - HVAC ducting design should be done to avoid conflicts with windows, so that the entire window can be visible and can operate as originally intended.
  - Other contemporary wiring and piping should be confined to the furred out areas when necessary.
  - It is preferable to have HVAC ducting and other service wiring and piping in attics or basements, or possible hallways, rather than interior rooms.

Figure 02 01-23 Before
Coronado Elementary School, Albuquerque, NM. Prior to renovation, lay-in ceilings had been installed, and ran into the middle of existing historic windows.

Figure 02 01-24 **Figure 02 01-25** After
In order to provide well-conditioned space that incorporated the full height of the original windows, gypsum board ceilings formed alcoves near the windows that pulled back to allow for a large portion of acoustical lay-in ceiling tile to be installed in each room.

CONSIDERATIONS FOR HISTORIC HIGH CEILINGS continued:

- **Energy Savings Potential:**
  - As described above in General Notes, this Guideline does not attempt to calculate the energy savings on the features discussed. It does offer some general energy savings information for consideration.
  - As described earlier, heat still rises to a high ceiling, away from occupants. However, in the wintertime, this condition is a negative. Some applications use ceiling fans, with the blades reversed, to move the warm air down to the occupants.
  - Where HVAC systems are being replaced with new, more efficient systems, the height of the rooms should be taken into consideration with the system design. Providing HVAC supply at the floor allows the heated air to rise past the occupants in the winter, and the cool air to stay with the occupants in the summer.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Since quantitative information on energy saving potential is not available for individual circumstances, there are no corresponding Cost Considerations.

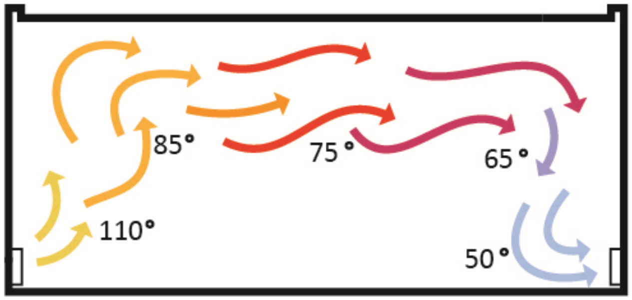


Figure 02 01-26 Typical air circulation in a room conditioned with a forced air system from below.

CONSIDERATIONS FOR HISTORIC OPERABLE WINDOWS:

- **Approach:**
  - Before powered air conditioning was accepted, rooms were designed with windows to provide cross ventilation in the summer. Outside air will not enter a room unless there is an outlet because the outside air cannot overcome the increased air pressure.
  - The best cross ventilation happens when the windows are at opposite sides of the room, so the air travels the full dimension of that room. However, corner rooms can also get good ventilation diagonally with proper window placement.
  - Cross ventilation is best used in the spring and fall of the year. A summer breeze of 95 degree air does not have much of a cooling factor. Likewise, one does not want to open windows in the winter.
  - Many new code requirements require a fresh air supply. Some codes require that it be part of the HVAC system, because occupants cannot be relied upon to open windows in the winter.
  - Operable windows are often desired by occupants for times when the HVAC system does not function properly in their part of the building.
  - Breezes from cross ventilation are not consistent and often cause disruptions to loose paperwork.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - Window design and placement is usually a character defining feature of a historic building.
  - Relocation of windows to achieve better cross ventilation will likely be discouraged by the SHPO.
  - Repairing windows so that they operate as originally intended is a frequent improvement to a historic building. See Guideline 08 01 Increasing Energy Efficiency in Historic Windows

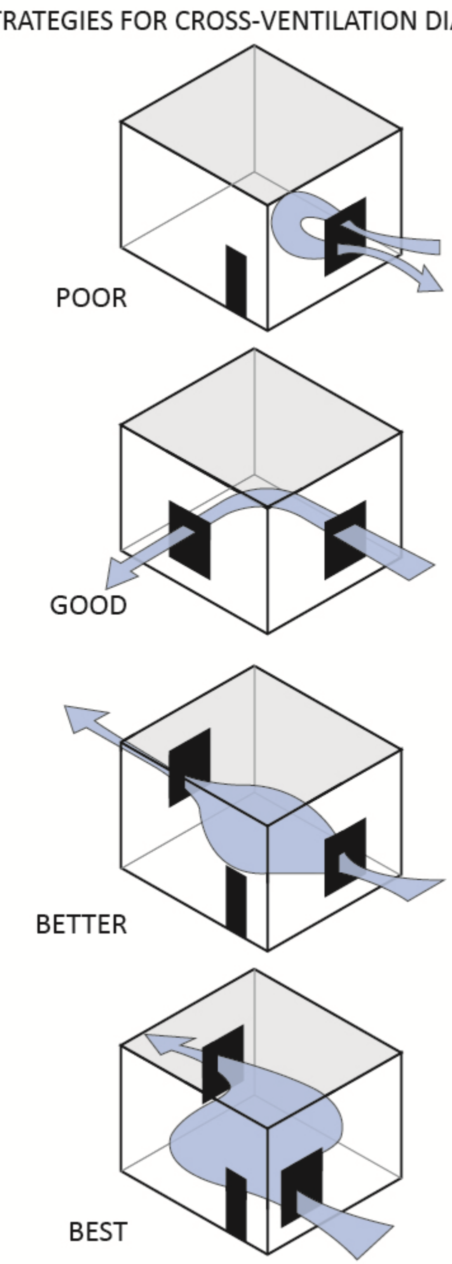


Figure 02 01-27 Strategies for cross-ventilation Diagram.

CONSIDERATIONS FOR HISTORIC OPERABLE WINDOWS continued:

- **Energy Savings Potential:**
  - As described above in General Notes, this Guideline does not attempt to calculate the energy savings on the features discussed. It does offer some general energy savings information for consideration.
  - Operable windows that provide cross ventilation can save energy even if only used in fall and spring.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Since quantitative information on energy saving potential is not available for individual circumstances, there are no corresponding Cost Considerations.

Figure 02 01-28 Office space ventilated with operable windows.

CONSIDERATIONS FOR HISTORIC UNDERCUT DOORS, TRANSOMS, AND ATTIC LOUVERS:

- **Approach:**
  - Undercut doors, usually cut 1" above the floor, allow for some cross ventilation to pass through the building.
  - Operating transoms above doors allow for cross ventilation in the summer. Transoms should be closed in winter.
  - Attic louvers also allow for cross ventilation to cool attics, thereby reducing the heat that can build up and transfer to the occupied portions of the building below. Ideally, louvers are closed in winter.
  - Contemporary fire codes limit the openings below doors and through transoms in some situations to reduce the transfer of smoke to escape routes during a fire.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Attic Louvers may be character defining features for the building exterior.
  - Transoms may be character defining features for the building interior.
  - Undercutting of doors is seldom a character defining feature.
  - Where transoms cannot be operable in a fire rated corridor, they should be retained with fire rated walls, painted black, behind the glass. In this fashion, the historical appearance of the corridor is retained while meeting the new fire code.

- **Energy Savings Potential:**
  - As described above in General Notes, this Guideline does not attempt to calculate the energy savings on the features discussed. It does offer some general energy savings information for consideration.

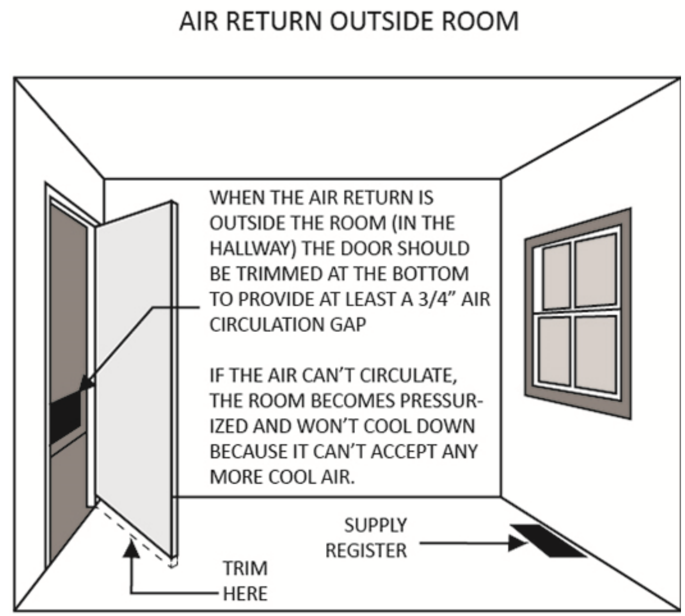


Figure 02 01-29 Undercut doors can be a useful strategy to achieve proper ventilation.

Figure 02 01-19 Attic louvers, Silver Hills Neighborhood, Albuquerque, NM.

CONSIDERATIONS FOR HISTORIC UNDERCUT DOORS, TRANSOMS, AND ATTIC LOUVERS continued:

- **Energy Savings Potential continued:**
  - Stuffed fabric tubes, called "draft dodgers," can be placed at the base of doors in the winter to prevent drafts. While the name might not be popular on military bases, the tubes are effective for doors that are not frequently used. For doors that are frequently used, a removable door "sweep" can be installed at the base of the door to reduce drafts.
  - Transoms can be closed for winter. If the transom is on an exterior door, a removable insulated panel can be installed.
  - With the SHPO's review and comment, the glass in a transom on an exterior door could be replaced with insulated glass.
  - Attic louvers can be closed in winter with insulated panels mounted on the inside of the louvers. Someone needs to be assigned to remove the insulation in the spring.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Since quantitative information on energy saving potential is not available for individual circumstances, there are no corresponding Cost Considerations.

Figure 02 01-31 Transom windows over doors in corridor

GUIDELINE DESCRIPTION: This Guideline will look at different insulation types for concrete walls (rigid, spray, batt insulation, and Exterior Insulation and Finish Systems (EIFS)). It will discuss insulation location, general aspects that pertain to the historic structure and discuss key points in the decision making process. These insulation types have similar approaches, the same SOI Standards and Historic Preservation effects. The information provided in this Guideline are ideas; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

Figure 03 31-1

Rigid

Figure 03 31-2

Spray foam

Figure 03 31-3

Batt insulation

RELATED GUIDELINES:

- 04 21 Insulating Masonry Walls, review for additional information on basement insulation.
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.

GENERAL NOTES:

- Non-significant interiors allow for more insulation options.
- Determine the affect insulation would have on the Thermal Mass properties.
- Basements / crawl spaces with concrete walls that are non-living, service spaces provide great opportunities for insulation.
  - o Ensure vapor barrier is facing the proper direction
  - o Ensure proper anchoring.
  - o Consider adding rigid foam to the bottom of exposed floor joists in the basement.
- This Guideline will not discuss the insulation of solid ground floors
  - o Not very common in the United States. The marginal benefit of the added insulation is offset by the loss of the historic floor and expense of floor removal and reinstallation.
- Buildings built in the 1970's used the most energy (Btu/ft2) of any period from 1920's-2010.
  - o Buildings from the 1960's are starting to become eligible for historic status.
  - o It is still important to preserve these buildings as part of our history.
- Buildings with concrete walls typically expose the concrete on both faces of the wall, therefore adding insulation to either the interior or exterior may affect the historic character. However, adding insulation to the interior might be acceptable.
  - o Poured concrete walls are solid without cavities which could be filled with insulation.
    - ▪ This type of construction is more commonly reaching historic status at this time.
    - ▪ Therefore, the addition of insulation is applied to the face of the wall.

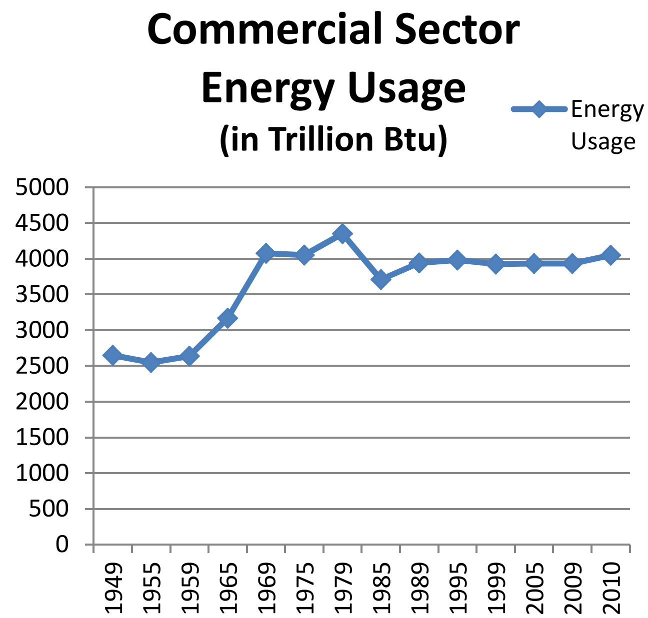


Chart 03 31-1 U.S. Energy Information Administration, Commercial Sector Energy Consumption Estimates 1949-2010, Released October 19, 2011, Updated August 2012

CONSIDERATION FOR RIGID INSULATION: applied to the interior

- **Approach:**
  - Ensure that the interior surface to be covered is non-significant
  - Work with Design Team to determine how the wall assembly works
    - Are there moisture issues?
    - Thermal Mass – analyze whether or not the wall mass already contributes significantly to reducing heating/cooling loads.
  - Determine the appropriate amount of insulation to achieve the desired energy goals.
  - Apply rigid insulation to the interior face of wall, fastening it to z furring channels
    - Has significant cultural resource concerns as this action would permanently change the concrete wall
    - Less expensive than full studs
  - Build a furrout with studs (wood or steel) and add insulation between the studs.
    - Installed properly, leaves wall intact, therefore no cultural resource concern or structural concerns. Must emphasize importance of keeping the wall intact.
    - More expensive but a heavier duty structure.
    - Can achieve greater thickness of insulation = higher R value.
    - Reduces usable sf in interior space more than direct application to wall.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - It is important to work with the CRM, Design Team and the local SHPO to ensure that the specific construction methods used will not adversely affect the building.
  - Adding insulation can cause interstitial condensation which can damage the structure. The Design Team must be knowledgeable about the combined effects of vapor barrier location and insulation.
  - If the interior is historically significant, careful collaboration with the CRM/SHPO is required to find acceptable solutions for all concerned parties.

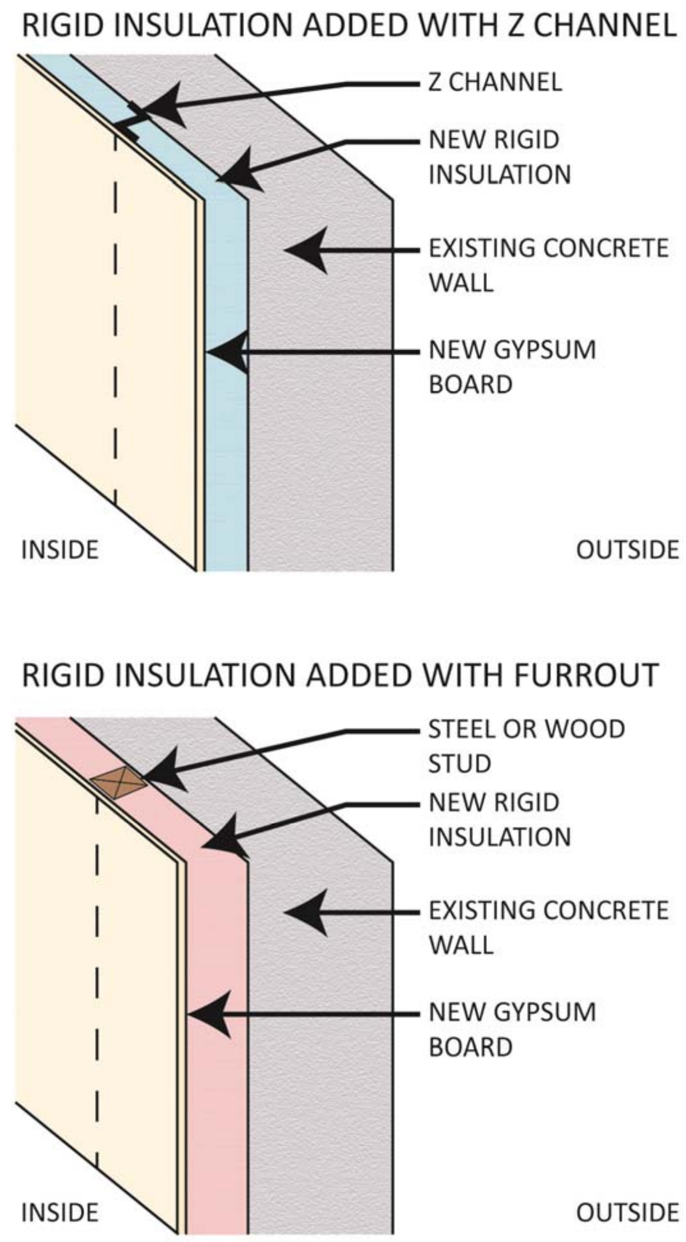


Figure 03 31-4

CONSIDERATION FOR RIGID INSULATION continued: applied to the interior

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - **Thermal Mass**: Concrete walls have a thermal mass that absorbs and releases heat due to the density of the concrete. In some climates, that have high temperature swings in a 24-hour period, the thermal mass might be used to heat the building in the colder parts of the day and it might be best to leave these walls un-insulated. The actual thermal mass of a wall should be figured by a professional who can analyze the specific situation of the wall, orientation of the wall and the climate.
    - The thermal mass of the concrete wall may impact the performance of the wall, but is not considered in these calculations. A professional analysis is recommended.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials**:**
      - Poured concrete wall thickness R = X/in x (wall thickness in inches) ___________
      - Rigid insulation (beadboard) ___________
      - Insulation structure (z channels) ___________
      - Gypsum board (sheet rock) ___________
  - **Assumptions** (both for the calculator and table)
    - That the concrete wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ___________
    - **Cost** - ___________
    - **Location -** ___________
    - **Total Heating Degree Days (HDD)-** ___________
    - **Total Cooling Degree Days (CDD) -** ___________

Sources:

R-Values

- *Concrete wall – American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Standard 90.1 2004*
- *Rigid Insulation and other materials - www.coloradoenergy.org/procorner/stuff/r-values.htm*

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR SPRAY FOAM INSULATION (POLYURETHANE OR CELLULOSIC), FIBERGLASS BATT, NATURAL FIBER BATT INSULATION: These types of insulation will have similar approaches, fall under the same SOI Standards and have the same Historic Preservation effects.

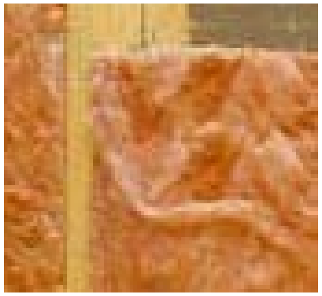
- **Approach:** Similar approach to rigid insulation
  - Ensure that the interior is non-significant or is being significantly altered for other reasons, thus making the addition of insulation a potential option.
  - Work with Design Team to determine how the wall assembly works
    - Are there moisture issues?
    - Thermal Mass – analyze whether or not the wall mass already contributes significantly to reducing heating/cooling loads.
  - Determine the appropriate amount of insulation to achieve the desired energy goals.
  - Differs from Rigid Insulation in that it requires the construction of an interior stud wall to provide a cavity for the insulation to go into.
    - Reduces the usable sf of the interior space.
    - Leaves concrete wall intact, therefore no Historic Preservation or structural concerns if properly discussed before construction.

      Special instructions needed for spray foam as it will bond to most surfaces (the concrete wall) that it is sprayed onto. This is almost always an adverse effect.
- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials
- **Historic Preservation Effects:**
  - It is important to work with the CRM and Design Team and the local SHPO to ensure that the specific construction methods used will not adversely affect the building.
  - Adding insulation can cause interstitial condensation which can damage the structure. The Design team must be knowledgeable about the combined effects of vapor barrier location and insulation.
  - It is also important to determine whether or not the interior is historically significant.
  - The addition of interior studs wall is not easily reversible
  - The original wall will not be visible from the interior.

Figure 03 31-5

Spray Foam

Figure 03 31-6



Fiberglass Batt Insulation

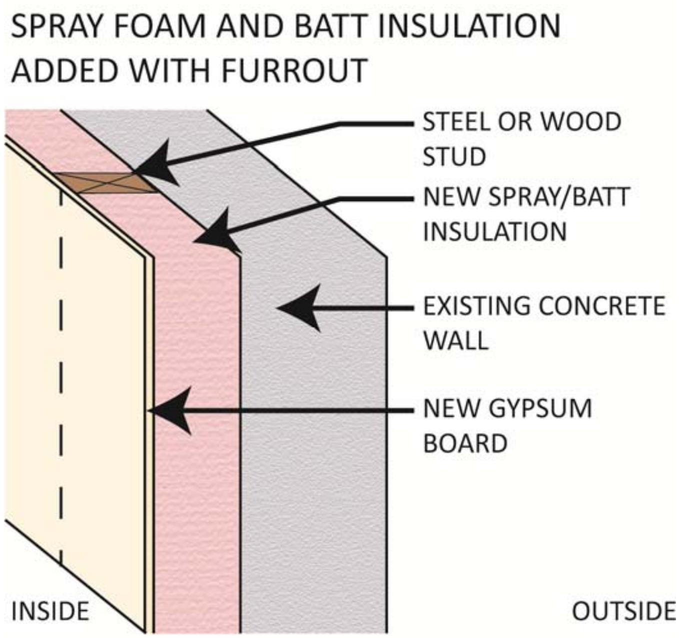


Figure 03 31-7 Very similar to rigid insulation in a furrout, except that with spray foam and batt insulation, the studs are typically much larger. Spray foam and batts rely much more on the stud structure whereas rigid insulation, as the name implies, is rigid by itself.

CONSIDERATION FOR SPRAY FOAM INSULATION (POLYURETHANE OR CELLULOSIC), FIBERGLASS BATT, NATURAL FIBER BATT INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - **Thermal Mass**: See description of and information regarding thermal mass on page 69.
  - Each insulation type has a different R-value.
  - Each insulation type has different air barrier and sound attenuation characteristics, which vary depending on the amount (thickness) of insulation installed.
  - Batts are a less expensive material, but can sag over time, reducing their effectiveness
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Poured concrete wall thickness R = X/in x (wall thickness in inches) ___________
      - Spray/Batt insulation ______________
      - Insulation structure (steel or wood stud) ______________
      - Gypsum board (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the concrete wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - There is significant cost associated with any of these options, as an entirely new stud wall must be built onto the inside of the existing concrete wall to house the insulation.
  - Different types of insulation have different manufacturing impacts – polyurethane spray foam insulation vs. cellulosic spray foam.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Concrete wall – ASHRAE Standard 90.1 2004*
- *Spray / Batt Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR EIFS:

Exterior Insulation and Finish Systems, multi-layered, exterior wall systems (EIMA)

- **Approach**: EIFS were first introduced in the United States almost 40 years ago.
  - EIFS typically consist of the following components:
    - Insulation board, made of polystyrene or polyisocyanurate foam, which is secured to the exterior wall surface with a specially formulated adhesive and/or mechanical attachment - the insulation layer
    - A durable, water-resistant base coat, which is applied on top of the insulation and reinforced with fiber glass mesh for added strength
    - A finish coat

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - "Adding rigid foam insulation to the exterior face of buildings…is never an appropriate treatment for historic buildings." (Hensley and Aguilar n.d., 12)
  - The addition of EIFS covers the historic façade of a building and changes the relationship to other historic elements like windows and doors.
    - The facades are usually the most easily recognizable historic element. They are often "character defining features".
    - EIFS are modern materials and change the recognized time period of a building.
    - It is difficult to differentiate between the old and new since the new covers the old.
  - **Such a drastic change as adding EIFS, violates the tenants of Historic Preservation and therefore cannot be recommended as a viable insulation technique. The impact to the structure is greater than what any energy saving might be.**

ABBREVIATION:

EIMA – EIFS Industry Members Association

Figure 03 31-8

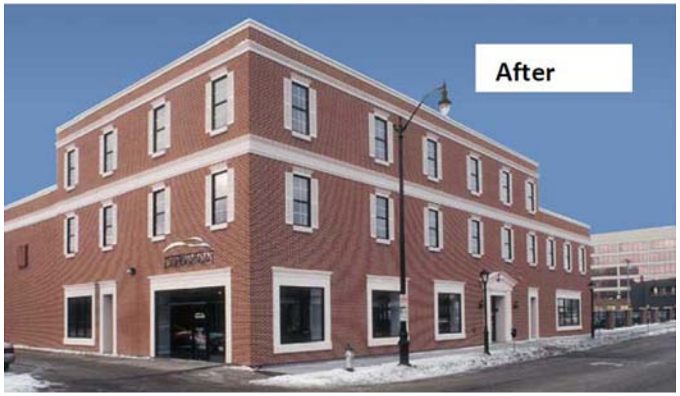


Figure 03 31-9

Dryvit (EIFS) Renovation completely changes the appearance of a building.

BMW Car Dealership, Springfield, Illinois

Designer: CDG Architects Engineers and Planners

GUIDELINE DESCRIPTION: This Guideline will explore the effectiveness of establishing an existing historic concrete wall as a heat sink, also known as a trombe wall, to help heat and cool the rest of the building. It will discuss the basic principles of a heat sink and will provide advice for decision making that is appropriate for the historic condition. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, review for additional information on basement insulation.
- 04 21 Insulating Masonry Walls, review for additional information on basement insulation.
- 04 41 Using Masonry Walls as Heat Sinks, review for additional information.
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.

GENERAL NOTES:

- Heat Sink is generally defined as "any environment or medium that absorbs heat." (Dictionary.com, "heat sink").
- Trombe Wall is generally a passive solar system used to heat and cool buildings that uses the thermal mass of a concrete wall along with solar gain and glazing properties. Specifically, it is a glass-fronted exterior concrete/masonry wall that absorbs solar heat for radiation into a building. (Dictionary.com, "trombe wall").
  - o Developed and patented by Edward S. Morse in 1881
  - o Named after Felix Trombe, who popularized the technology in 1964 with architect Jacques Michel
  - o (Saadatian et al., "Trombe walls: A review," 2012, 6341)
- In historic buildings, the addition of a trombe wall is most applicable on buildings that already have existing dark colored concrete, no feasible possibility of adding insulation, and the existing wall requires protection from the elements.
- A trombe wall will most likely not be the sole source for heating and cooling in the building, but can help drastically reduce the energy consumption needed by conventional systems.

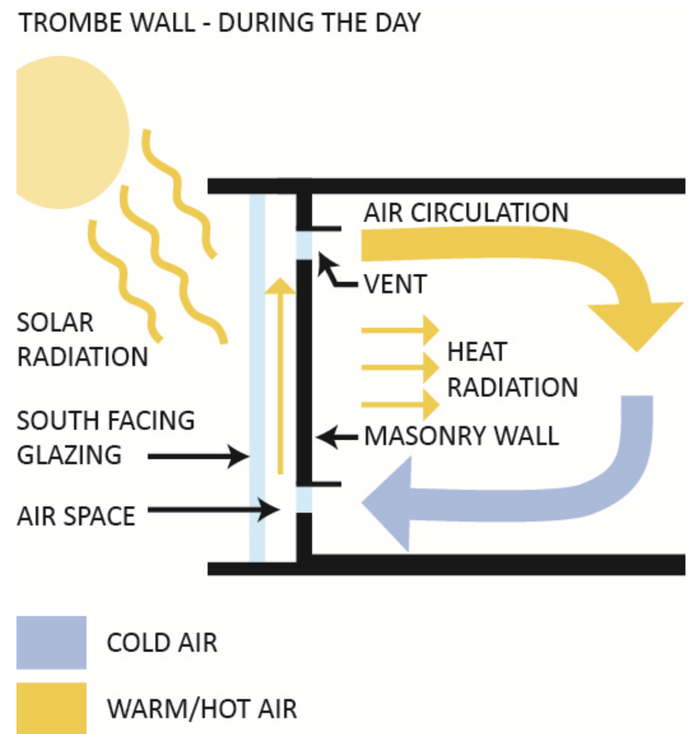


Figure 03 41-1

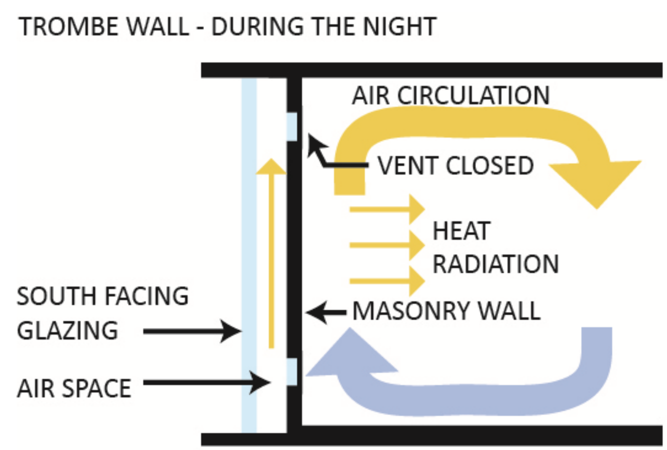


Figure 03 41-2

CONSIDERATIONS FOR ADDING A TROMBE WALL:

- **Approach:**
  - Determine the status of the façade to have glass covering it.
    - Is it historically significant?
    - What is the orientation? South-facing is ideal.
    - What is the concrete wall color? Dark/black is ideal.
    - What is the condition? Level of deterioration?
    - What is the percentage of area with existing windows/openings?
  - Work with Design Team to determine how the existing wall assembly works
    - Are there moisture issues?
    - Climate? Cold climate, face winter sun. Warm climate, avoid direct sunlight.
      - Overhangs can be utilized to avoid direct summer sun and allow direct winter sun. Does the existing building have overhangs or other features that can be utilized by the trombe wall?
    - Thermal Mass – analyze whether or not the wall mass already contributes significantly to reducing heating/cooling loads.
    - Determine whether there are existing openings that can be used as vents or if adding vents will harm the historic character.
      - Vents are open during winter to allow heat inside the building.
      - Vents are closed during the summer to keep the heat out of the building.
  - Determine specific variation of trombe wall.
    - Regular trombe wall with a few inch air gap.
    - Trombe wall as a sun space / vestibule.
    - Water wall, water containers which absorb heat faster than concrete and can transfer heat into the space faster.
    - Solar Chimney, a form of passive ventilation where vents at the top of the glazing create a convection current and pull air from the room.
    - (Autodesk Education Community, "Trombe Walls and Attached Sunspace," 2011)

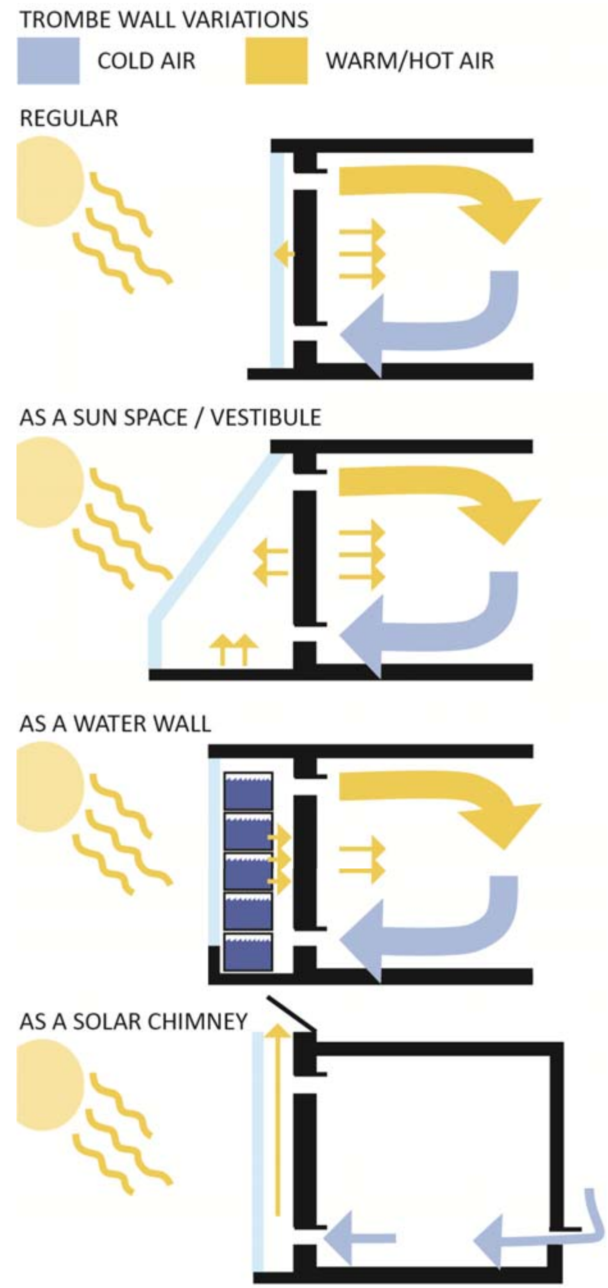


Figure 03 41-20

CONSIDERATIONS FOR ADDING A TROMBE WALL continued:

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - It is important to work with the CRM, Design Team and the local SHPO to ensure that the specific construction methods used will not adversely affect the building.
  - Adding glass to the façade can drastically change the character of the building. The Design Team must carefully consider how such an addition will impact the structure.
  - Additionally, the variations of different types of trombe walls can have drastically different impacts on the historic character.
    - The use of a water wall or sun space / vestibule has much greater visual impacts for example than simply adding glass a few inches from an existing dark wall.

Concrete Zigzag Trombe wall, located in North Carolina

Figure 03 41-4
Note: The zigzag trombe wall is like the Classic trombe wall except that the different sections used to create the zig zag are oriented to avoid overheating during summer months. Therefore, it is possible to add a trombe wall to a building even if the walls are not perfectly straight.

CONSIDERATIONS FOR ADDING A TROMBE WALL continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
    - **Thermal Mass**: Concrete walls have a thermal mass that absorbs and releases heat due to the density of the concrete. The actual thermal mass of a wall should be figured by a professional who can analyze the specific situation of the wall, orientation of the wall and the climate.
    - **Passive Thermal Systems:** Passive, by definition, does not involve a "visible reaction or active participation." Therefore, it is extremely difficult to quantify the energy saving potential of using a trombe wall in a building. Additionally, only one façade is typically a trombe wall and all exterior walls contribute to a building's heating and cooling needs. The best option would be to analyze utility bills before and after the renovation to determine the amount of energy saved with the trombe wall addition.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
    - Does the façade in question already require repairs or other maintenance work? If so, the addition of glass could be a relatively minor expense, especially if the work required is due to exposure to the elements.
    - The biggest expense associated with this option is the design and analysis needed to determine the best façade and construction technique.

Sources:

R-Values

- *Concrete wall – American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Standard 90.1 2004*
- *Rigid Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

GUIDELINE DESCRIPTION: This Guideline will look at different types of insulation for masonry walls (rigid, spray, batt insulation, and EIFS). It will discuss insulating inside versus outside, and will provide advice for decision making that is appropriate for the historic condition. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, review for additional information on basement insulation.
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.

GENERAL NOTES:

- For the purposes of this document Concrete Masonry Units (CMU) will be covered here since the applicable insulation techniques for CMU match those used for of other types of masonry walls, such as stone masonry.
- Review Guideline 07 21 Thermal Insulation for steps in evaluating the existing building conditions for the specific building. Basement insulation follows similar principles outlined under this section and in Guideline 03 31 Insulating Concrete Walls, as basements and crawl spaces are typically masonry or concrete construction.
- Walls designed with Thermal Mass – adding insulation within the wall affects these properties
- Non-significant interiors allow for more insulation options
- Basement/crawl spaces that are non-living, service spaces provide great opportunities for insulation. However, older masonry foundations, especially stone, can have uneven walls making adding insulation to the walls nearly impossible. Therefore, adding insulation to the basement ceiling is recommended as an alternative.
    - o Vapor barrier must face up to keep any moisture from condensing on the floor structure side of the insulation.
    - o Ensure proper anchoring for moist situations.
    - o Rigid insulation over the bottom of the floor joist is common practice

Figure 04 21-1 CMU Wall, above

Figure 04 21-2 Repointed Historic brick wall, above

Figure 04 21-3 Stone wall, above

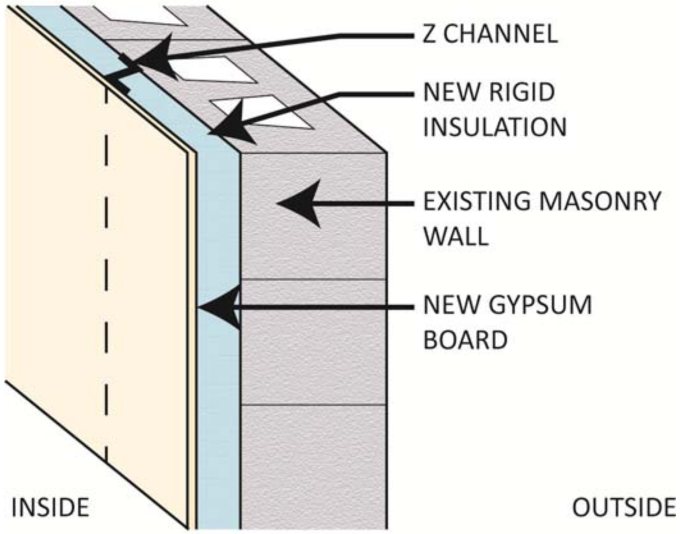
CONSIDERATIONS FOR RIGID INSULATION: applied to the interior

- **Approach:**
  - Ensure that the interior is non-significant or is being significantly altered for other reasons, thus making the addition of insulation a potential option.
  - Work with Design Team to determine how the wall assembly works
    - Moisture issues – Determine whether or not there are any
    - Thermal Mass – analyze whether or not the wall mass already contributes significantly to reducing heating/cooling loads.
  - Determine the appropriate amount of insulation to achieve the desired energy goals.
  - Apply rigid insulation to the interior face of wall fastening to z furring channels
    - Permanently changes the wall, a significant cultural resource concern
    - Might not be possible if the historic wall has settled significantly and is not plumb, or if the material is too brittle and fragile to hold additional load.
    - Less expensive than full studs
  - Build a furrout with studs (wood or steel) and add insulation between the studs.
    - Leaves wall intact, therefore no cultural resource concern or structural concerns.
      - Must emphasize importance of keeping the wall intact to ensure that it is done.
    - More expensive but more significant structure.
    - Can achieve greater thickness of insulation = higher R value.
    - Reduces more usable sf of interior space than direct application

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - It is important to work with the CRM and Design Team and the local SHPO to ensure that the specific construction methods used will not adversely affect the building, especially if the interior is historically significant.
  - Adding insulation can cause interstitial condensation which can damage the structure. Be knowledgeable about the combined effects of vapor barrier location and insulation.

RIGID INSULATION ADDED WITH Z CHANNEL



RIGID INSULATION ADDED WITH FURROUT

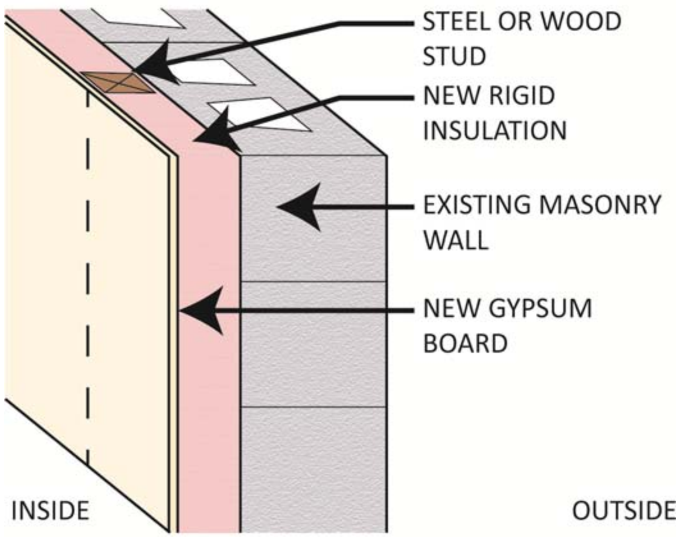


Figure 04 21-4

CONSIDERATION FOR RIGID INSULATION continued: applied to the interior

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - **Thermal Mass**: Masonry walls have a thermal mass that absorbs and releases heat due to the density of the masonry, and infill. In some climates, that have high temperature swings during a 24-hour period, the thermal mass might be used to heat the building in the colder parts of the day and it might be best to leave these walls un-insulated. The actual thermal mass of a wall should be figured by a professional who can analyze the specific situation of the wall, the orientation of the wall and the climate.
    - The thermal mass of the masonry wall may impact the performance of the wall, but is not considered in these calculations. A professional analysis is recommended.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials**:**
      - Masonry wall thickness R = X/in x (wall thickness in inches) ______________
      - Wall infill (grout, insulation) ______________
      - Rigid insulation (beadboard) ______________
      - Insulation structure (z channels or studs) ______________
      - Gypsum board (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the masonry wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Masonry wall – ASHRAE Standard 90.1 2004*
- *Rigid Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR SPRAY FOAM INSULATION (POLYURETHANE):

- **Approach:**
  - Typical insulation used to fill cavity spaces in historic masonry walls (Walls and Foundations of Historic Buildings n.d., 8).
  - Also can be used to fill the hollow cells of Concrete Masonry Units (CMU)
  - Pneumatically applied, polyurethane expands to fill a space once it reacts with the air.
  - General Recommendations prior to application (Gonçalves n.d., 5).
    - Repair all holes to ensure a sound substrate for insulation. Remove all loose materials (mortar, plaster parging) and clean all surfaces to ensure that the insulation will adhere.
    - The air barrier and insulation (sprayed polyurethane foam) should be continuous at the floor joists, floor slabs and adjacent components, including window interface, to ensure continuity of the air barrier and insulation system.
    - Transition membranes are suggested at critical locations, like window perimeters.
    - The International Building Code stipulates specific requirements with regards to fire stops in wall assemblies. It is important that these requirements be verified with the local building code professional.
    - Indoor relative humidity levels and building pressurization should be controlled to minimize vapor pressure gradients (and moisture migration) across wall assemblies.

- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.
  - Can cause interstitial condensation (See 07 21 Thermal Insulation)
    - If not properly ventilated, moisture stays, causing major damage over time.

Figure 04 21-5

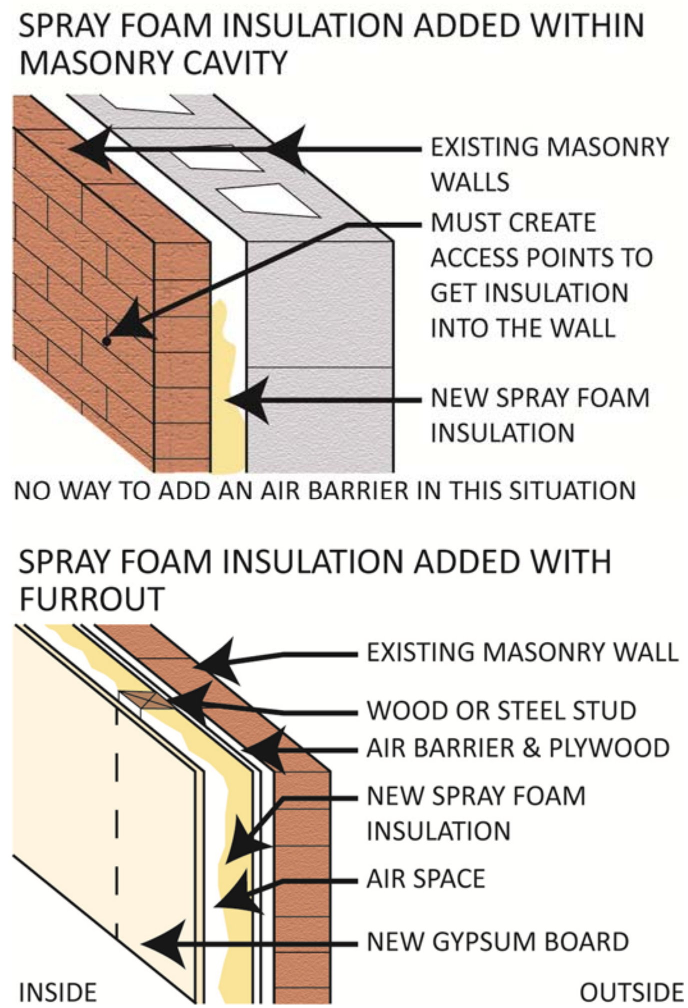


Figure 04 21-6

CONSIDERATION FOR SPRAY FOAM INSULATION (POLYURETHANE) continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - **Thermal Mass**: See description of and information regarding thermal mass on page 27.
  - Advantages of using spray foam insulation (polyurethane) (Gonçalves n.d., 4):
    - The polyurethane foam acts as the main air barrier material of the wall assembly with transition membranes installed at critical locations, like window perimeters.
    - It provides excellent air tightness characteristics.
    - It provides continuity at junctions with floor joists and slabs, walls, ceilings, floors and window perimeter, which is important to avoid flow of indoor air at these areas.
    - It can be applied over irregular surfaces, and total thickness can be controlled.
  - Vapor permeance depends on insulation thickness & substrate (Gonçalves n.d., 4).
  - Addition of liquid vapor barrier applied directly to the interior face of the insulation is recommended to provide a continuous high-performance vapor barrier to wall assembly (Gonçalves n.d., 3).
    - Main moisture transfer addressed with an effective and continuous air barrier, therefore vapor permeance is not as critical.
  - The alternative to a liquid vapor barrier is a sheet barrier system: typically a sheet barrier (also known as building wrap) acts as both an air and water barrier and is mechanically fastened to the building substrate.
  - Advantages of liquid vapor barrier over sheet barrier system:
    - Continuity at junctions (ceilings, floors, window perimeters, etc.) is easily achieved without interfering with services within finished wall assembly.
    - The coating, which is applied directly to the insulation, is protected from punctures during construction or by occupants.
    - Long term effects are not fully documented.
  - Both liquid and sheet barriers can be difficult, if not impossible to add in historic buildings. The Design Team must consider if the risks to the historic structure and historic characteristics are worth the advantages of adding the vapor barrier and even the insulation itself.

Figure 04 21-7 Liquid barrier, looks like black tar

Figure 04 21-8 Sheet barrier, looks like opaque plastic

CONSIDERATION FOR SPRAY FOAM INSULATION (POLYURETHANE) continued:

- **Energy Savings Potential continued:**
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials**:**
      - Note: Depending on each particular situation, not all of the below R-values will be present in the wall assembly.
      - Masonry wall thickness R = X/in x (wall thickness in inches) ___________
      - Wall infill (grout or spray foam insulation) ______________
      - Spray foam insulation (polyurethane) ______________
      - Insulation structure (z channels or studs) ______________
      - Air space ______________
      - Gypsum board (sheet rock) ______________
      - Vapor barrier (liquid or sheet) ______________
  - **Assumptions** (both for the calculator and table)
    - That the masonry wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Masonry wall – ASHRAE Standard 90.1 2004*
- *Spray Foam Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR BLOWN IN / INJECTED: Mineral wool, beads or granules.

- **Approach**:
  - For Masonry, must access from the top of the wall
  - Applied pneumatically
  - Vapor retarders might not be necessary for above ground walls depending on specific conditions

- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is Compatible with Historic

- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.
  - **Difficult access increases the chances of damaging historic details**

Figure 04 21-9

INSULATION GRANULES

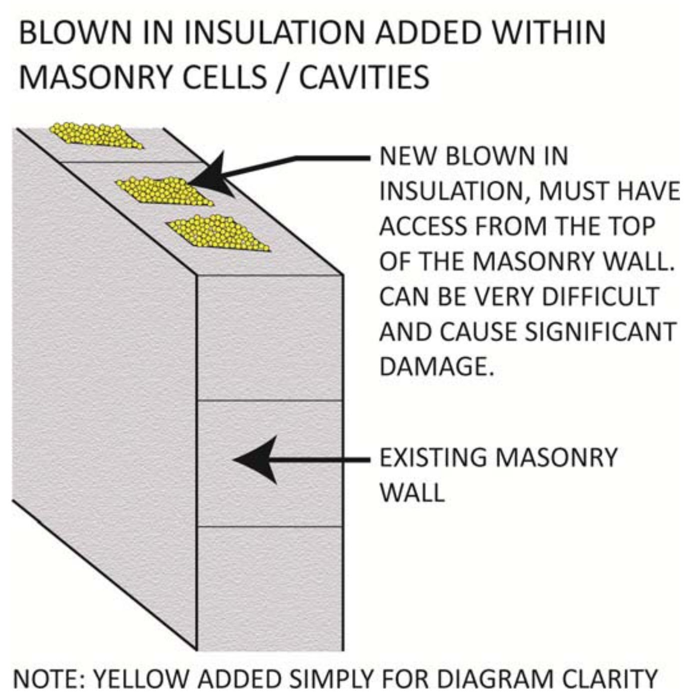


Figure 04 21-10

CONSIDERATION FOR BLOWN IN / INJECTED continued: Mineral wool, beads or granules.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - **Thermal Mass**: See description of and information regarding thermal mass on page 31.
  - Blown in / injected insulation provides more complete fill than other insulations, therefore giving a more consistent R-value throughout the entire assembly.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Masonry wall thickness R = X/in x (wall thickness in inches) ___________
      - Blown in / Injected Insulation ______________
  - **Assumptions** (both for the calculator and table)
    - That the masonry wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Masonry wall – ASHRAE Standard 90.1 2004*
- *Blown in / Injected Insulation -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR EIFS:

Exterior **I**nsulation and **F**inish **S**ystems – multi-layered exterior wall systems (EIMA)

- **Approach**: EIFS were first introduced in the United States almost 40 years ago.
  - EIFS typically consist of the following components:
    - Insulation board, made of polystyrene or polyisocyanurate foam, which is secured to the exterior wall surface with a specially formulated adhesive and/or mechanical attachment - the insulation layer
    - A durable, water-resistant base coat, which is applied on top of the insulation and reinforced with fiber glass mesh for added strength
    - A finish coat
- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 9: New Work is Compatible with Historic
- **Historic Preservation Effects:**
  - "Adding rigid foam insulation to the exterior face of buildings…is never an appropriate treatment for historic buildings." (Hensley and Aguilar n.d., 12).
  - The addition of EIFS covers the historic façade of a building and changes the relationship to other historic elements like windows and doors.
    - The facades are usually the most easily recognizable historic element. They are often "character defining features".
    - EIFS is a modern material and changes the recognized time period of a building.
    - It is difficult to differentiate between the old and new since the new covers the old.
  - **Such a drastic change, as adding EIFS, violates the tenants of Historic Preservation and therefore cannot be recommended as a viable insulation technique. The cost to the structure is greater than what any energy saving might be**.

Figure 04 21-11

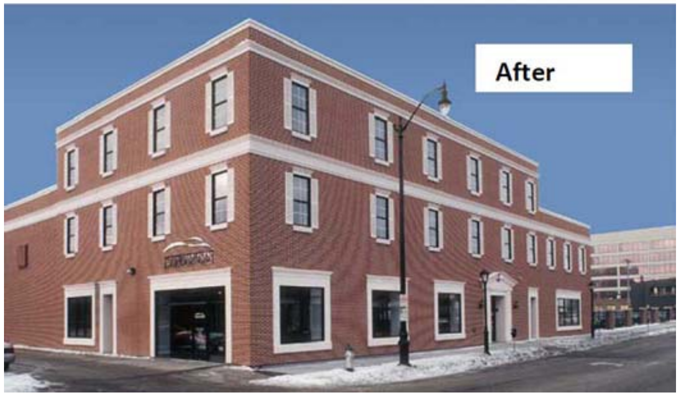


Figure 04 21-12

Dryvit (EIFS) Renovation completely changes the appearance of a building.

BMW Car Dealership, Springfield, Illinois

Designer: CDG Architects Engineers and Planners

GUIDELINE DESCRIPTION: This Guideline will explore the effectiveness of establishing an existing historic masonry wall as a heat sink, also known as a trombe wall, to help heat and cool the rest of the building. It will discuss the basic principles of a heat sink and will provide advice for decision making that is appropriate for the historic condition. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, review for additional information on basement insulation.
- 03 41 Using Concrete Walls as Heat Sinks, review for additional information.
- 04 21 Insulating Masonry Walls, review for additional information on basement insulation.
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.

GENERAL NOTES:

- Heat Sink is generally defined as “any environment or medium that absorbs heat.” (Dictionary.com, “heat sink”).
- Trombe Wall is generally a passive solar system used to heat and cool buildings that uses the thermal mass of a masonry wall along with solar gain and glazing properties. Specifically, it is a glass-fronted exterior concrete/masonry wall that absorbs solar heat for radiation into a building. (Dictionary.com, “trombe wall”).
    - Developed and patented by Edward S. Morse in 1881
    - Named after Felix Trombe, who popularized the technology in 1964 with architect Jacques Michel
    - (Saadatian et al., “Trombe walls: A review,” 2012, 6341)
- In historic buildings, the addition of a trombe wall is most applicable on buildings that already have existing dark colored masonry, no feasible possibility of adding insulation, and the existing wall requires protection from the elements.
- A trombe wall will most likely not be the sole source for heating and cooling in the building, but can help drastically reduce the energy consumption needed by conventional systems.

Figure 04 41-1 CMU Wall

Figure 04 41-2 Repointed Historic brick wall

Figure 04 41-3 Stone wall

CONSIDERATIONS FOR ADDING A TROMBE WALL:

- **Approach:**
  - Determine the status of the façade to have glass covering it.
    - Is it historically significant?
    - What is the orientation? South-facing is ideal.
    - What is the masonry color? Dark/black is ideal.
    - What is the condition? Level of deterioration?
    - What is the percentage of area with existing windows/openings?
  - Work with Design Team to determine how the existing wall assembly works.
    - Are there moisture issues?
    - Climate? Cold climate, face winter sun. Warm climate, avoid direct sunlight.
      - Overhangs can be used to avoid direct summer sun and allow direct winter sun. Does the existing building have overhangs or other features that can be utilized by the trombe wall?
    - Thermal Mass – analyze whether or not the wall mass already contributes significantly to reducing heating/cooling loads.
    - Determine whether there are existing openings that can be used as vents or if adding vents will harm the historic character.
      - Vents are open during winter to allow heat inside the building.
      - Vents are closed during the summer to keep the heat out of the building.
  - Determine specific variation of trombe wall.
    - Regular trombe wall with a few inch air gap.
    - Trombe wall as a sun space / vestibule.
    - Water wall, water containers which absorb heat faster than concrete and can transfer heat into the space faster.
    - Solar Chimney, a form of passive ventilation where vents at the top of the glazing create a convection current and pull air from the room.
    - (Autodesk Education Community, "Trombe Wall and Attached Sunspace," 2011)

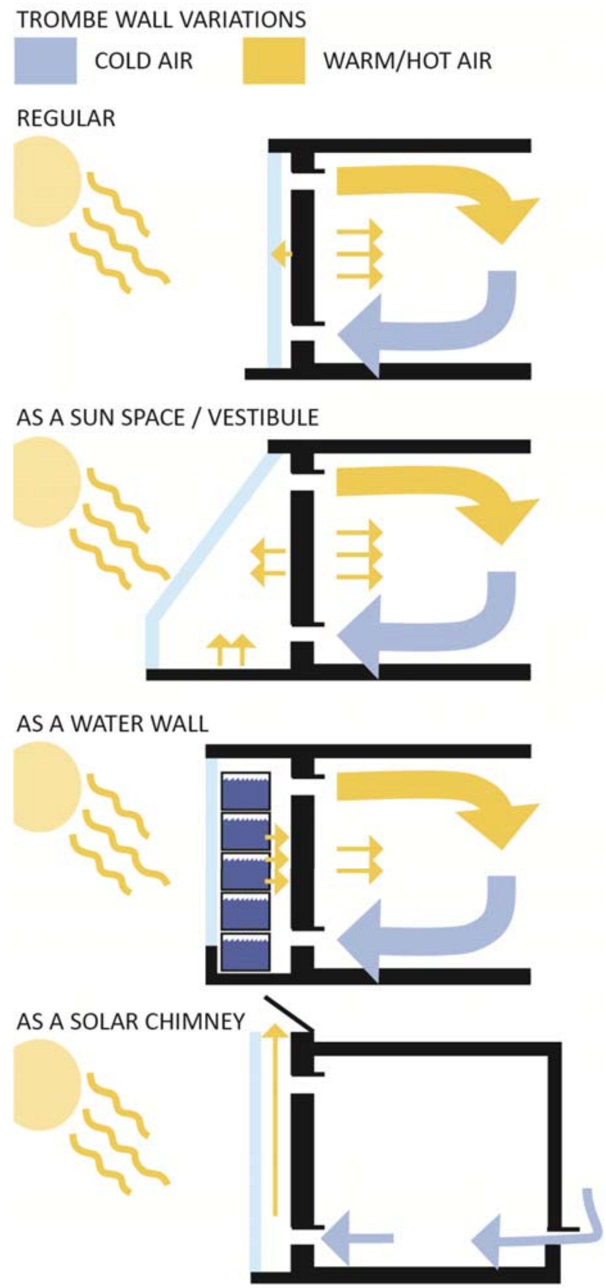


Figure 04 41-4

CONSIDERATIONS FOR ADDING A TROMBE WALL continued:

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - It is important to work with the CRM, Design Team and the local SHPO to ensure that the specific construction methods used will not adversely affect the building.
  - Adding glass to the façade can drastically change the character of the building. The Design Team must carefully consider how such an addition will impact the structure.
  - Additionally, the variations of different type of trombe walls can have drastically different impacts on the historic character.
    - The use of a water wall or sun space / vestibule has much greater visual impacts for example than simply adding glass a few inches from an existing dark wall.

Note: Images to the right
Zion National Park Visitor Center contains many energy saving features which work together for an annual energy savings of $14,000 per year from a 74.4% energy use reduction. (2006 Figures) (National Park Service, “Zion Canyon Visitor Center,” 2014).

One of those features is a trombe wall on the south side of the building. The lower portion is a trombe wall, a single glazing over masonry with a selective surface coating. The upper portion contains daylighting and vision glazing as can be seen in both the photograph and section detail. (Torcellini and Pless, “Trombe Walls in Low-Energy Buildings,” 2004) and (Williams College, “Passive Solar Design,” 2014).

SECTION THOUGH TROMBE WALL

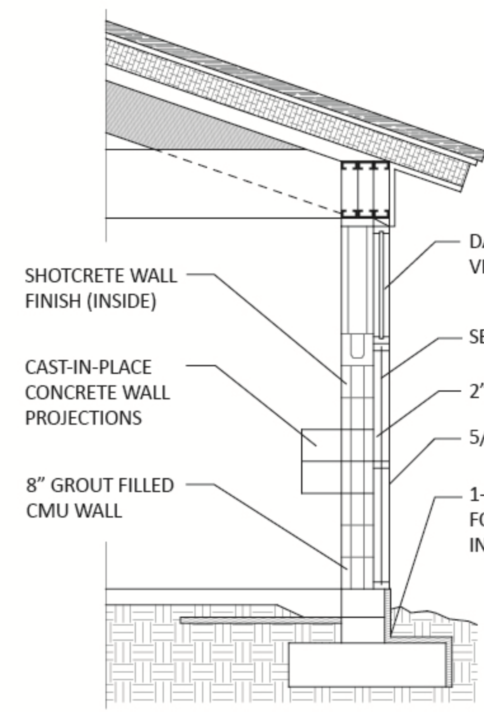


Figure 04 41-5 Zion National Park Visitor Center

Figure 04 41-6 Photograph of South Façade

CONSIDERATIONS FOR ADDING A TROMBE WALL continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - **Thermal Mass**: Masonry walls have a thermal mass that absorbs and releases heat due to the density of the masonry. The actual thermal mass of a wall should be figured by a professional who can analyze the specific situation of the wall, orientation of the wall and the climate.
  - **Passive Thermal Systems:** Passive, by definition, does not involve a "visible reaction or active participation." Therefore, it is extremely difficult to quantify the energy saving potential of using a trombe wall in a building. Additionally, only one façade is typically a trombe wall and all exterior walls contribute to a building's heating and cooling needs. The best option would be to analyze utility bills before and after the renovation to determine the amount of energy saved with the trombe wall addition.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Does the façade in question already require repairs or other maintenance work? If so, the addition of glass could be a relatively minor expense, especially if the work required is due to exposure to the elements.
  - The biggest expense associated with this option is the design and analysis needed to determine the best façade and construction technique.

Sources:

R-Values

- *Masonry wall – ASHRAE Standard 90.1 2004*
- *Rigid Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-an gas-cost-state

HDD and CDD

- www.degreedays.net/

Glass Entrance addition to a Historic Building

Figure 04 41-7 Note: An example of an acceptable addition to a historic building that can also be a trombe wall. According to Preservation Brief 14 "This glass addition was erected at the back of an 1895 former brewery during rehabilitation to provide another entrance. The addition is compatible with the plain character of the secondary elevation." (Grimmer et al. 2010).

GUIDELINE DESCRIPTION: This Guideline will discuss air barriers for reducing air infiltration on existing historic metal buildings. Metal roofs, window frames and insulation options have been discussed in conjunction with other chapters in Phase I. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet Unified Facilities Criteria (UFC) requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, review for additional information on basement insulation.
- 04 21 Insulating Masonry Walls, review for additional information on basement insulation.
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 07 92 Using New Joint Sealants on Historic Components
- 08 01 Increasing Energy Efficiency in Historic Windows
- 08 41 Reducing Air Transfer at Historic Doors/Entrances

GENERAL NOTES:

- The purpose of the building envelope is to protect the building occupant from the outside elements, namely excess heat, cold and precipitation. Today, users also expect to be able to control the interior environment of a building through the use of HVAC systems.
- Energy-efficient envelopes focus on reducing air infiltration and thermal performance.
- Air infiltration is considered a bigger problem than the amount of insulation because if a wall leaks, the insulation is irrelevant. Therefore, it is critical to consider how much air filters through the building envelope and its effect on the thermal performance of the building. Refer to the discussion in Guideline 00 01 Project Organization on Energy Audits.
- It is important to note that historic buildings were built with technology designed to "leak" to prevent mold growth. Careful analysis is needed of the existing conditions to determine whether the air infiltration is due to deterioration or part of the initial design.
- Maintenance: if the system includes sealants, the typical replacement time frame varies greatly between 7 and 20 years. Ensure proper compatibility with the historic system and new sealant. Refer to Guideline 07 92 Using New Joint Sealants on Historic Components.
- Air barriers are either vapor impermeable or vapor permeable. Both can be either mechanically attached, self-adhered or fluid applied. Continuity is a key to preventing infiltration.

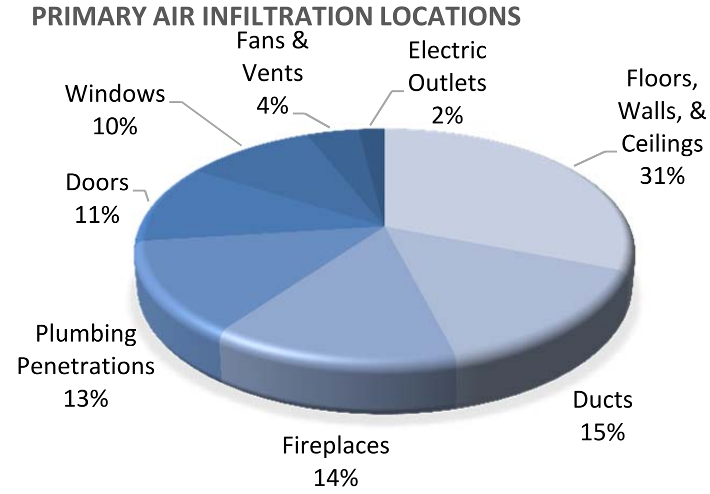


Chart 05 41-1 Data Source: U.S. Department of Energy

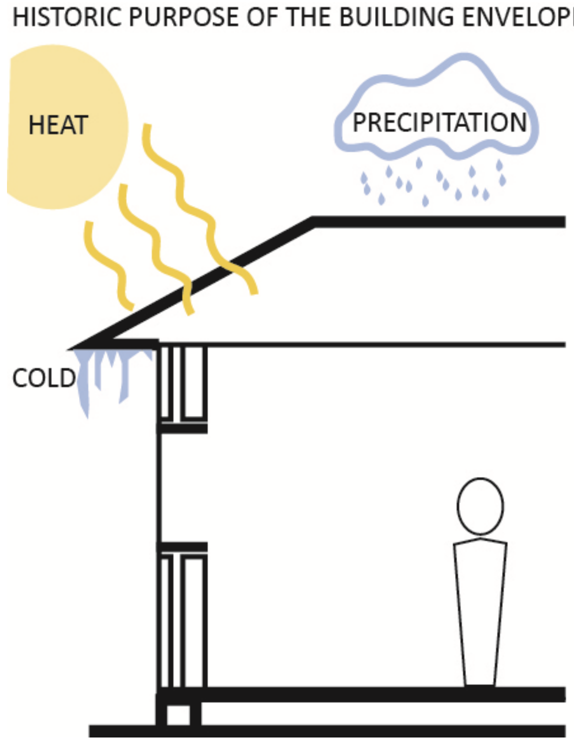


Figure 05 41-1

CONSIDERATIONS FOR ADDING AN AIR BARRIER:

- **Approach:**
  - Conduct a careful analysis of the existing building envelope.
  - Determine the status of the building envelope.
    - Does it require additional maintenance and restoration to be functional?
    - Does the system already contain insulation? Condition of such?
    - If there is not existing insulation, is the addition of such being considered?
    - What surfaces are easily accessible as to respect the historic integrity?
    - What is the existing flashing system?
  - Work with Design Team to determine the proper location of the air barrier
    - Air barriers can be located anywhere in the building enclosure.
    - In cold climates, typically use an interior air barrier system
    - In warm or windy climates, the air barrier is typically located near the exterior.
    - (Lstiburek "Understading Air Barriers," 2006)
  - Work with Design Team to determine the type of air barrier: vapor permeable or impermeable.
    - Are there moisture issues in which vapor needs to be eliminated?
  - Air barrier systems should be:
    - Impermeable to air flow
    - Continuous over the entire building enclosure or continuous over the enclosure of any given unit
    - Able to withstand the forces that may act on them during and after construction
    - Durable over the expected lifetime of the building
    - (Lstiburek "Understading Air Barriers," 2006)

CONTEMPORARY PURPOSE OF THE BUILDING ENVELOPE

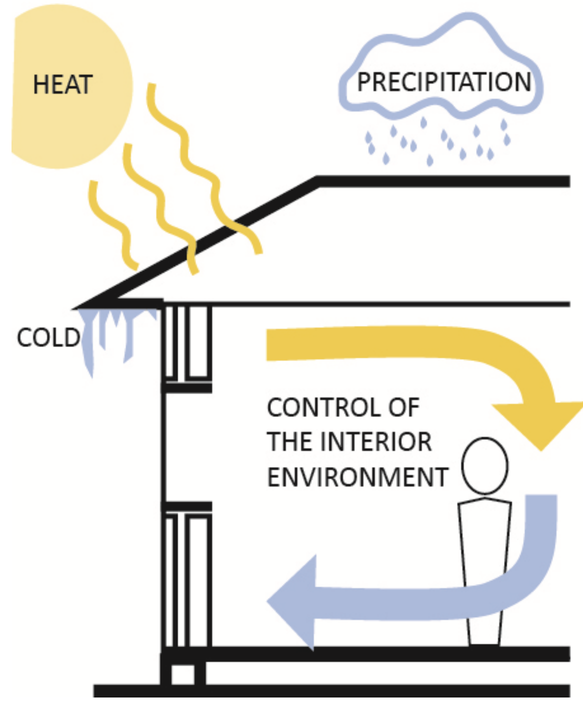
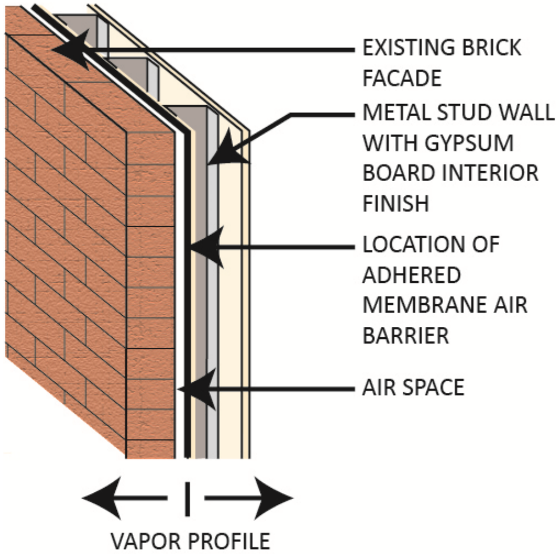


Figure 05 41-1

CONSIDERATIONS FOR ADDING AN AIR BARRIER continued:

- **Approach continued:**
  - Common installation techniques: (Lstiburek "Understading Air Barriers," 2006)
    - Exterior Air Barrier System using self-adhered modified bituminous membrane sheets
      - Typically used in roofing applications, therefore ensure that the specific product purchased is acceptable for the intended use.
      - This cost information does not take into account the expenses incurred from accessing the barrier location on an existing historic structure.
      - Historic Effect: This type of barrier is not a finishing system and therefore is not meant to be visible. However, the challenge is gaining access to the proper location for the barrier in such a way that does not damage/change a visible historic component.
        - Because of the difficulty in accessing (having to remove and reinstall historic components), this system is really only feasible if the historic components need to be removed for other reasons.
    - Exterior Air Barrier System using precast, site-cast or tilt-up concrete panels
      - Not recommended since it would drastically change the exterior character of the building.

ADHERED MEMBRANE LOCATION WITH BRICK FACADE



ONLY ACCESSIBLE IF THE OTHER COMPONENTS OF THE WALL ASSEMBLY NEED TO BE REMOVED

Figure 05 41-3

EXTERIOR BARRIOR ON PRECAST

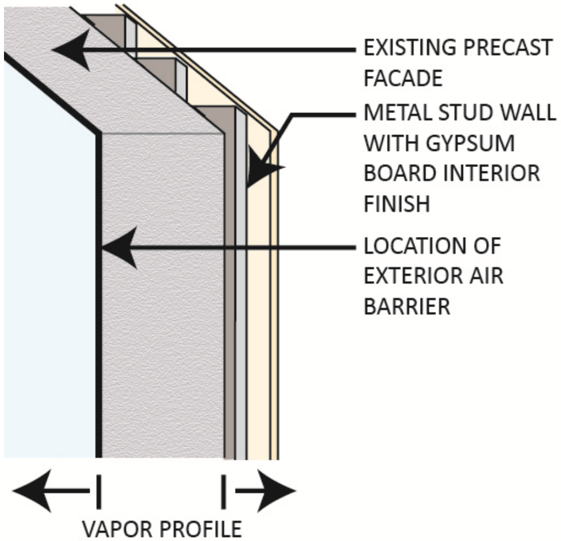


Figure 05 41-4

CONSIDERATIONS FOR ADDING AN AIR BARRIER continued:

- **Approach continued:**
  - Interior Air Barrier System using gypsum board, see figure 05 41-5.
    - If the interior finish already needs to be replaced for other reasons, this is one of the most feasible options for a historic building.
      - The cost of the interior air barrier system could be absorbed in the cost of a necessary renovation project. The "cost" of the air barrier could be zero as long as consideration was given to the placement and type of gypsum board specified in regards to the air barrier.
  - Interior Air Barrier System using sheet polyethylene
    - Polyethylene sheets are a type of plastic that comes in many different grades and formulations and is classified as Low, Medium or High density. The different grades have drastically different properties ranging from flexible to rigid, clear to opaque.
      - Exact type depends on climate, adhesion technique needed / other envelope materials being used. Discuss specifics with Design Team.
    - General characteristics include: tough, excellent chemical resistance and electrical properties, low COF (coefficient of friction), near-zero moisture absorption, light weight and easy to process.
    - Historic Effect: highly dependent on exact type of polyethylene as well as the specific historic materials of the project.
      - Like the bituminous membrane, polyethylene sheets are not meant to be a finish material and visible on a finished project. Therefore, installation would require access from some point in the wall. If the interior finish already needs to be removed / replaced for other reasons and the building requires a more substantial air barrier than the gypsum board, then polyethylene sheets are a logical option to consider.

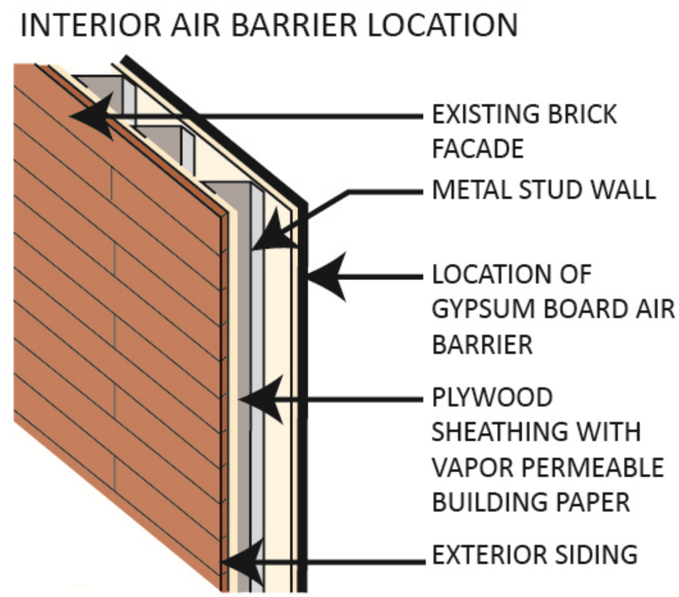


Figure 05 41-5

CONSIDERATIONS FOR ADDING AN AIR BARRIER continued:

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - It is important to work with the CRM, Design Team and the local SHPO to ensure that the specific construction methods used will not adversely affect the building.
  - Each type of barrier has different historic preservation effects as well as performance characteristics. Look at each type of barrier specifically for its impact on the building.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - **Part of a system:** The air barrier is part of the larger building envelope system. It cannot be analyzed for its specific energy savings potential. For a more general discussion on determining the energy savings potential of the entire exterior building envelope, see Guidelines 03 31 Insulating Concrete Walls and 04 21 Insulating Masonry Walls.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Does the façade in question already require repairs or other maintenance work? If so, the addition of an air barrier could be a relatively minor expense or even negligible if the air barrier can serve multiple purposes.
  - One of the biggest expenses associated with this option is the design and analysis needed to determine the feasibility and type of air barrier system.
  - The other major expense is the potential removal and reinstallation of historic materials to gain access to the location for the air barrier.
  - Therefore, it is recommended that the addition of an air barrier would typically be used in conjunction with another renovation project on the exterior envelope so that the cost is distributed among several different renovation projects.

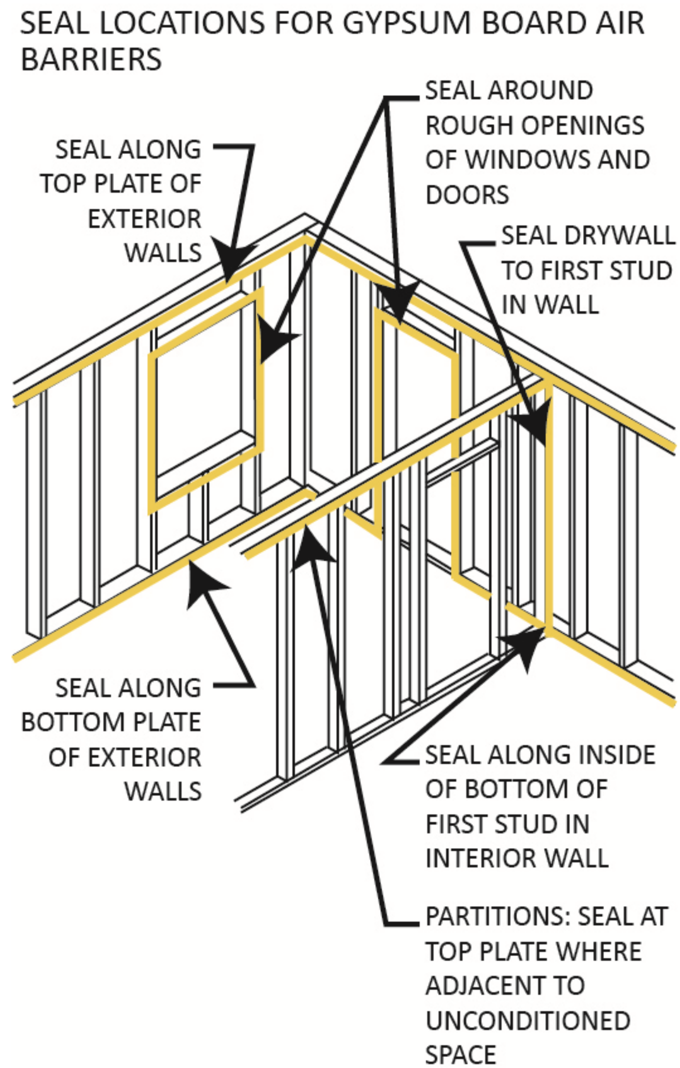


Figure 05 41-6

GUIDELINE DESCRIPTION: This Guideline will look at the different types of insulation and how each affects a structure clad in metal panels. Much of the information is similar to that found in Guideline 06 81 Insulating Wood Structures as the assumption is made that the structure is (metal) stud framing. It will establish applicable techniques (when to remove and replace panels; how to address the process of removing and replacing, keeping track of pieces; rain screens; and blown in insulation). It will also provide a decision making process that is appropriate for the historic condition. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

Figure 05 51-1 Rust damage to metal studs

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, review for Basement insulation.
- 04 21 Insulating Masonry Walls, review for Basement insulation.
- 06 81 Insulating Wood Structures
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 07 31 Insulation for Sloped Roofs, review for Attic insulation.

GENERAL NOTES:

- Moisture entrapment is the critical issue when discussing adding insulation to historic buildings. Moisture entrapment can cause irreparable damage from rust and corrosion. (National Trust for Historic Preservation, "PreservationNation," 2014).
- Non-significant interiors allow for more insulation options.
- It is assumed in the case of DoD specific buildings, that most of the buildings with historic metal panels are hangers, warehouses, or storehouses. It is also assumed that if these buildings are to be renovated, that they are being renovated into a use other than their original function. These assumptions further lead that the new interior will require a higher degree of finish than that of a hanger, warehouse or storehouse that might simply have exposed studs. Changing the interior finishes, in turn, leads to more options for insulation.

CONSIDERATIONS FOR NATURAL FIBER INSULATIONS: (wood, plant fiber)

- **General Info:**
  - Especially recommended by the National Trust.
    - Breathability, especially in attic spaces.
    - Sustainability – tend to be more renewable, can be made from recycled materials, do not release harmful substances during decomposition, etc.
    - Because they are organic materials, they can support mold if not kept dry.

- **Approach:**
  - Installed via blown-in or as batts, see following sections on the specific approach.
  - Can be difficult to find a manufacturer in specific areas.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - Natural fibers are most compatible with historic materials.
  - These materials will cause the least damage to the structure, but the full effects cannot be evaluated without considering the specific installation technique used.
  - Some organic fibers, being organic material, can support mold. Mold can damage historic and other materials. Check the manufacturer's recommendations, and be sure that no moisture can accumulate in the fibers.

Figure 05 51-2

Figure 05 51-3

Figure 05 51-4

CONSIDERATION FOR NATURAL FIBER INSULATIONS continued: (wood, plant fiber)

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Natural fiber insulations vary greatly in individual R-values based not only on material but also on installation technique.
  - They also tend to be a little lower than poly insulations but comparable or a little better than fiberglass batts.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Exterior Sheathing ______________
      - Metal frame structure ______________
      - Natural Fiber Insulation ______________
      - Gypsum board (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the metal framed wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Natural fiber insulation is not as wide-spread, and so is still more expensive than fiberglass batts.
  - Cost of natural fiber insulation is comparable to spray foam insulation (see sources)
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Metal Structure –ASHRAE Standard 90.1 2004*
- *Natural Fiber Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm and http://www.ecorate.com/content/products.aspx?cid=28

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR BLOWN-IN INSULATION:

- **Approach:**
  - Walls: Insulation can settle at the bottom of the wall over time, reducing its effectiveness (over time, gravity can cause batts to sag also).
  - Dense-packed cellulose or fiberglass causes the least amount of damage to historic material/finishes when there is access.
    - Density will reduce settling.
  - Dense-packed cellulose is most common.
    - R-value, relatively simple installation, etc…
  - Access
    - Have to drill holes as access points
      - Inside or outside but very dusty
    - Also used in cantilevered floors, under attic stairs and odd spaces behind knee walls.
  - Comes in at least 2 grades based on fire retardant added
    - Mix of ammonium sulfate and boric acid
    - Boric acid only – borate only – recommended for historic buildings as sulfates react with moisture and can corrode metal (Hensley 2011).

- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is Compatible with Historic

- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.

BLOWN IN INSULATION ADDED IN A METAL STRUCTURE

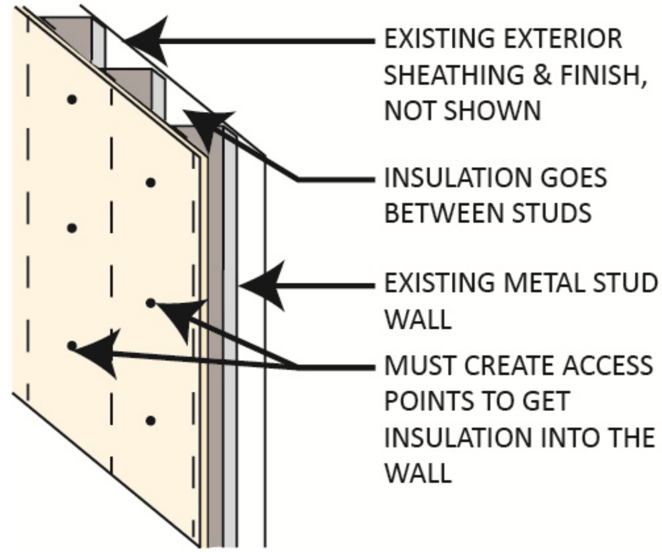


Figure 05 51-5

Figure 05 51-6
Interior Renovation Application

CONSIDERATIONS FOR BLOWN-IN INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Blown-in insulation provides more complete fill than other insulations, therefore giving a more consistent R-value throughout the entire assembly.
  - Air-seal: insulation material is crammed in, not fluffed in. At 3.5 pounds per cubic foot, it is too dense for air to infiltrate but still has R-value (Lugano 1996).
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Exterior Sheathing ____________
      - Metal frame structure ____________
      - Blown-In Insulation ____________
      - Gypsum board (sheet rock) ____________
  - **Assumptions** (both for the calculator and table)
    - That the metal framed wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Inexpensive option (Lugano 1996).
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - _____________
    - **Cost** - _____________
    - **Location -** _____________
    - **Total Heating Degree Days (HDD)-** _____________
    - **Total Cooling Degree Days (CDD) -** _____________

Sources:

R-Values

- *Wood Structure _ ASHRAE Standard 90.1 2004*
- *Blown-In Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR FIBERGLASS BATT INSULATION:

- **Approach:**
  - Only feasible if wall cavity is already open or if the interior is not historic and will be redone for other reasons.
  - Need tight fit so air spaces are not created. If insulation is too short or it is too long and bunched up, air pockets are created which reduces thermal performance.
  - Unfaced, friction-fit batt insulation, fluffed to fill entire cavity is recommended.
  - Split around obstacles instead of compressed on one side.

- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.
  - Difficult access increases the chances of damaging historic details.

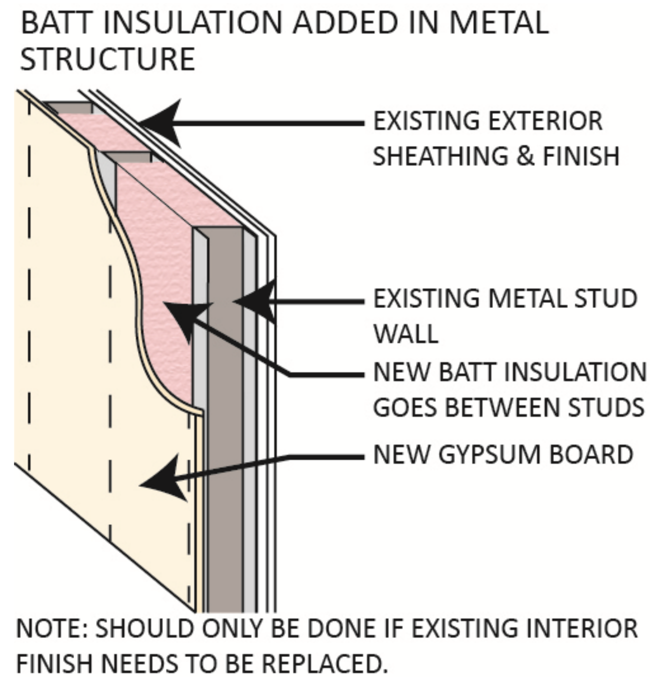


Figure 05 51-7

Figure 05 51-8 Metal stud wall, almost ready for insulation.

CONSIDERATIONS FOR FIBERGLASS BATT INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Fiberglass batt insulation likely has the least energy savings of all other insulations.
    - Insulation can settle
    - Inconsistent R-value throughout assembly
    - Provides no air barrier
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Exterior Sheathing ____________
      - Metal frame structure ____________
      - Fiberglass Batt Insulation ____________
      - Gypsum board (sheet rock) ____________
  - **Assumptions** (both for the calculator and table)
    - That the metal framed wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Inexpensive option (Lugano 1996).
  - Very common so most know how to install (but not necessarily in historic buildings).
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source -** _____________
    - **Cost -** _____________
    - **Location -** _____________
    - **Total Heating Degree Days (HDD)-** _____________
    - **Total Cooling Degree Days (CDD) -** _____________

Sources:

R-Values

- *Wood Structure _ ASHRAE Standard 90.1 2004*
- *Fiberglass Batt Insulation and other materials* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR SPRAY FOAM INSULATION (POLYURETHANE):

- **Approach:**
  - Guideline will only provide basic information.
    - Might be acceptable in a certain, project-specific situation, but would require in-depth/careful analysis on the part of the Design Team of both the energy savings, monetary and historic cost to the structure.
  - Pneumatically applied polyurethane expands to fill a space once it reacts with the air.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:** All considered Disadvantages
  - Adding insulation to an existing metal structure is always difficult, especially when trying to maintain the historic integrity of the space.
  - Spray foam can be considered a chemical treatment.
  - Not easily reversible – bonds tightly to framing.
  - Expansion rate of the foams can damage interior historic features.
  - Relatively new material, so there are questions about long term health effects.

- **Energy Savings Potential:** Considered Advantages
  - High R-value, compared to other insulations.
  - Functions as an air barrier.
  - Tight fit around obstacles.

Figure 05 51-9 Notice when the foam is initially sprayed, it is relatively flat, but expands beyond the extent of the studs.

Figure 05 51-10 When installed by an experienced contractor, spray foam can fill and seal around difficult to reach areas.

CONSIDERATIONS FOR USING THE HISTORIC METAL PANELS AS A RAIN SCREEN:

- **Approach: The term rain screen is often misused even within the industry.**
  - Definition according to the American Institute of Architects (AIA): Rain screen is the exterior cladding of a rain screen assembly. A rain screen assembly should comply with the rain screen principle. (Lough and Altenhofen, "The Rain Screen Principle").
  - Rain Screen Principle as described by G.K. Garden in 1963:
    - Wall assembly which incorporates "an air chamber into the joint or wall where the air pressure is always equal to that on the outside" and "prevents wetting of the actual wall or air barrier of the building." (Garden 1963).
  - **A Rain Screen is NOT a form of insulation.** However, it protects the wall behind from moisture and eliminates moisture penetration concerns with adding insulation.
  - Early examples of buildings utilizing the rain screen principle, like the Alcoa building pictured right are becoming eligible for historic status.
  - Successful applications tend to be new construction with modern technology. Therefore, this principle is not recommended for historic structures.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - It is important to be aware of the principle, since buildings with this type of technology are becoming historic.
  - **Such a drastic change as adding a Rain Screen violates the tenants of Historic Preservation and therefore cannot be recommended as a viable technique. The impact to the structure is greater than what any energy saving might be.**

Figure 05 51-11 The Alcoa Building in Pittsburg, PA (now the Regional Enterprise Tower) was built in 1953. It is a 30 story skyscraper and used 1/8" thick aluminum panels with open, labyrinth-type, pressure-moderating joints.

Rainscreen Resource:

NeaCera Terra-cotta Solutions, and Avenere Cladding LLC. **"Rainscreen Principles,"** 2014 2007. http://www.averecladding.com/why-neacera/rainscreen/rainscreen-principles/

GUIDELINE DESCRIPTION: This Guideline will look at the different types of insulation and how each affects wood construction. It will establish applicable techniques (when to remove and replace wood; how to address the process of removing and replacing, keeping track of pieces; which side to insulate; and blown in insulation). It will also provide a decision making process that is appropriate for the historic condition. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, review for Basement insulation.
- 04 21 Insulating Masonry Walls, review for Basement insulation.
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 07 31 Insulation for Sloped Roofs, review for Attic insulation.

GENERAL NOTES:

- Moisture entrapment is the critical issue when discussing adding insulation to historic buildings, especially to wood structures. Moisture entrapment can not only lead to mold growth but to the rotting of the wood structure itself, causing irreparable damage. (National Trust for Historic Preservation 2012).
- National Trust states "Like masonry walls, timber framed walls are also difficult to insulate without altering their appearance or creating a potentially damaging situation. Depending on the original construction method and the extent to which the walls have deteriorated and/or need maintenance/replacement, infill insulation could be installed within a timber frame wall. But again, this is for walls that have irreparable damage or prior renovations or alterations." (National Trust for Historic Preservation 2012).
- Non-significant interiors allow for more insulation options.

Figure 06 81-1

Figure 06 81-2

Images of mold, rot and termite damage in a 30 year old structure that did not have proper exterior water drainage or proper barriers. Repair was extensive both on the interior and exterior. Such situations are even more critical with historic structures.

CONSIDERATIONS FOR NATURAL FIBER INSULATIONS: (wood, plant fiber)

- **General Info:**
  - especially recommended by the National Trust
    - Breathability, especially in attic spaces
    - Sustainability – tend to be more renewable, can be made from recycled materials, do not release harmful substances during decomposition, etc….
    - Because they are organic materials, they can support mold if not kept dry.

- **Approach:**
  - Installed via blown-in or as batts, see following sections on the specific approach.
  - Can be difficult to find a manufacturer in specific areas.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - Natural fibers are most compatible with historic materials
  - These materials will cause the least damage to the structure, but the full effects cannot be evaluated without considering the specific installation technique used.
  - Some organic fibers, being organic material, can support mold. Mold can damage historic and other materials. Check the manufacturer's recommendations, and be sure that no moisture can accumulate in the fibers.

Figure 06 81-3

Figure 06 81-4

Figure 06 81-5

CONSIDERATION FOR NATURAL FIBER INSULATIONS continued: (wood, plant fiber)

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Natural fiber insulations vary greatly in individual R-values based not only on material but also on installation technique.
  - They also tend to be a little lower than poly insulations but comparable or a little better than fiberglass batts.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials**:**
      - Exterior Sheathing ______________
      - Wood frame structure ______________
      - Natural Fiber Insulation ______________
      - Gypsum board (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the wood framed wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Natural fiber insulation is not as wide-spread, and so is still more expensive than fiberglass batts.
  - Cost of natural fiber insulation is comparable to spray foam insulation (see sources)
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)**- ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Wood Structure –ASHRAE Standard 90.1 2004*
- *Natural Fiber Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm and http://www.ecorate.com/content/products.aspx?cid=28

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR BLOWN-IN INSULATION:

- **Approach:**
  - Walls: Insulation can settle at the bottom of the wall over time, reducing its effectiveness (over time, gravity can cause batts to sag also)
  - Dense-packed cellulose or fiberglass causes the least amount of damage to historic material/finishes <u>when there is access (taking a siding board from the top, exterior that can be reinstalled easily)</u>
    - Density will reduce settling
  - Dense-packed cellulose most common
    - R-value, relatively simple installation, etc…
  - Access
    - Have to drill holes as access points
      - Inside or outside but very dusty
    - Also used in cantilevered floors, under attic stairs and odd spaces behind kneewalls.
  - Comes in at least 2 grades based on fire retardant added
    - Mix of ammonium sulfate and boric acid
    - Boric acid only – borate only – recommended for historic buildings as sulfates react with moisture and can corrode metal (Hensley and Aguilar n.d.).

- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is Compatible with Historic

- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.
  - Difficult access, such as cutting access holes in the exterior, historic wood siding, increases the chances of damaging historic details

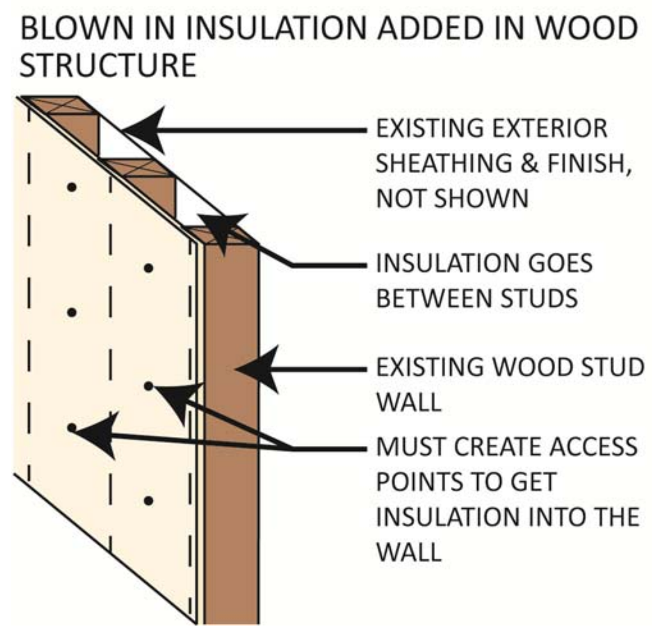


Figure 06 81-6


Figure 06 81-7 **Figure 06 81-8**

Interior and Exterior Renovation Applications

CONSIDERATIONS FOR BLOWN-IN INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Blown-in insulation provides more complete fill than other insulations, therefore giving a more consistent R-value throughout the entire assembly.
  - Air-seal: insulation material is crammed in, not fluffed in. At 3.5 pounds per cubic foot, it is too dense for air to infiltrate but still has R-value (Lugano 1996).
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Exterior Sheathing ____________
      - Wood frame structure ____________
      - Blown-In Insulation ____________
      - Gypsum board (sheet rock) ____________
  - **Assumptions** (both for the calculator and table)
    - That the wood framed wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Inexpensive option (Lugano 1996).
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - _____________
    - **Cost** - _____________
    - **Location -** _____________
    - **Total Heating Degree Days (HDD)-** _____________
    - **Total Cooling Degree Days (CDD) -** _____________

Sources:

R-Values

- *Wood Structure _ ASHRAE Standard 90.1 2004*
- *Blown-In Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR FIBERGLASS BATT INSULATION:

- **Approach:**
  - Only feasible if wall cavity is already open or if the interior is not historic and will be redone for other reasons.
  - Need tight fit so air spaces are not created. If insulation is too short or it is too long and bunched up, air pockets are created which reduces thermal performance
  - Unfaced, friction-fit batt insulation, fluffed to fill entire cavity recommended
  - Split around obstacles instead of compressed on one side

- **Applicable Secretary of the Interior Standards:**
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - Must ensure that the addition of insulation does not damage the existing structure.
  - Insulation can be difficult to install and to remove, causing damage to the original, historic wall and detailing.
  - Difficult access increases the chances of damaging historic details

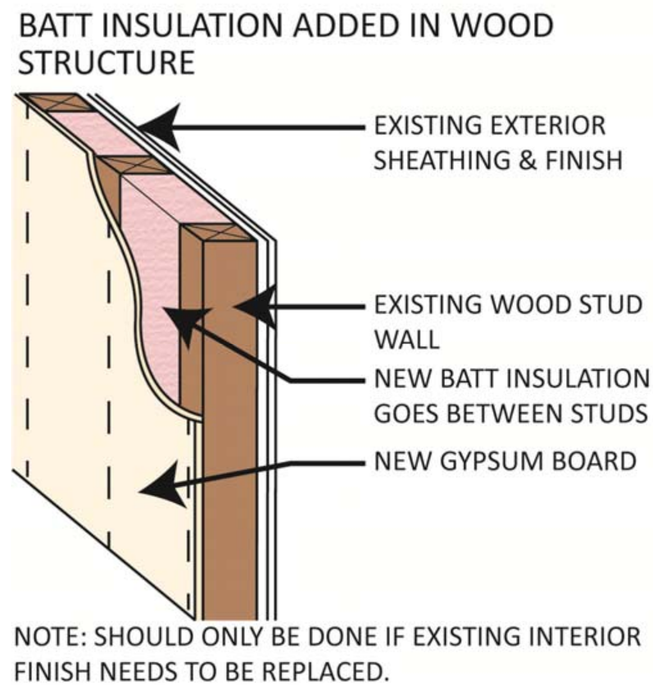


Figure 06 81-9

Figure 06 81-10 Installed faced batts in a wood stud wall.

CONSIDERATIONS FOR FIBERGLASS BATT INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Fiberglass batt insulation likely has the least energy savings of all other insulations.
    - Insulation can settle
    - Inconsistent R-value throughout assembly
    - Provides no air barrier
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for wall materials:
      - Exterior Sheathing ____________
      - Wood frame structure ____________
      - Fiberglass Batt Insulation ____________
      - Gypsum board (sheet rock) ____________
  - **Assumptions** (both for the calculator and table)
    - That the wood framed wall is exposed to outside temperatures (not basement).
    - That all walls are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Inexpensive option (Lugano 1996).
  - Very common so most know how to install (but not necessarily in historic buildings).
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source -** _____________
    - **Cost -** _____________
    - **Location -** _____________
    - **Total Heating Degree Days (HDD)-** _____________
    - **Total Cooling Degree Days (CDD) -** _____________

Sources:

R-Values

- *Wood Structure _ ASHRAE Standard 90.1 2004*
- *Fiberglass Batt Insulation and other materials* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR SPRAY FOAM INSULATION (POLYURETHANE):

- **Approach:**
  - **Is not recommended for historic wood structures as wall cavity insulation because it hinders air flow and can lead to wood rot.**
  - Guideline will only provide basic information.
    - Might be acceptable in a certain, project-specific situation, but would require in-depth/careful analysis on the part of the Design Team of both the energy savings, monetary and historic cost to the structure.
  - Pneumatically applied polyurethane expands to fill a space once it reacts with the air.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:** All considered Disadvantages
  - Adding insulation to an existing wood structure is always difficult, especially when trying to maintain the historic integrity of the space.
  - Spray foam can be considered a chemical treatment.
  - Not easily reversible – bonds tightly to framing
  - Expansion rate of the foams can damage interior historic features
  - Relatively new material so there are questions about long term health affects

- **Energy Savings Potential:** Considered Advantages
  - High R-value, compared to other insulations
  - functions as an air barrier
  - tight fit around obstacles
  - **The advantages of Spray Foam over other insulations do not outweigh the significantly higher risks and costs associated with this product. Therefore, it is not recommended as a viable insulation technique.**

Figure 06 81-11 Notice when the foam is initially sprayed, it is relatively flat, but expands beyond the extent of the studs.

Figure 06 81-11 Trimming is not a feasible option in a Historic Structure

GUIDELINE DESCRIPTION: This Guideline is different than many of the others in that it advocates the removal of materials to expose the original historic components. It will look at how the original energy saving aspects of the structure and how certain renovation practices of the past can detract from the character of the building and, ultimately, increase energy costs. Use this Guideline in conjunction with Guideline 06 81 Insulating Wood Structures to determine the best avenue for the building in question. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, review for Basement insulation.
- 04 21 Insulating Masonry Walls, review for Basement insulation.
- 06 81 Insulating Wood Structures
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 07 31 Insulation for Sloped Roofs, review for Attic insulation.

GENERAL NOTES:

- Why Reuse
  - Energy Savings of embodied energy – no "new" energy is expended to harvest, transport, process, and build a wood structure. Reusing existing framing, even if not visible, is a common sense choice if it is in good condition.
  - Lighting
    - Drop ceilings were/are a common renovation technique employed when additional space is needed for modern HVAC, electrical, and data ducts, piping and wiring.
      - Drop ceilings – reduce natural light, equal more energy in lighting
  - Health considerations
    - Asbestos ceiling tiles used until the 1970's. Many renovations to historic structures that occurred before 1980 will contain some form of asbestos.
    - A recent study linked the visual presence of wood to a lowered sympathetic nervous system (SNS) reaction. "The SNS is responsible for physiological stress responses in humans."
  - (Fell 2011) and (Rice et al. 2006).

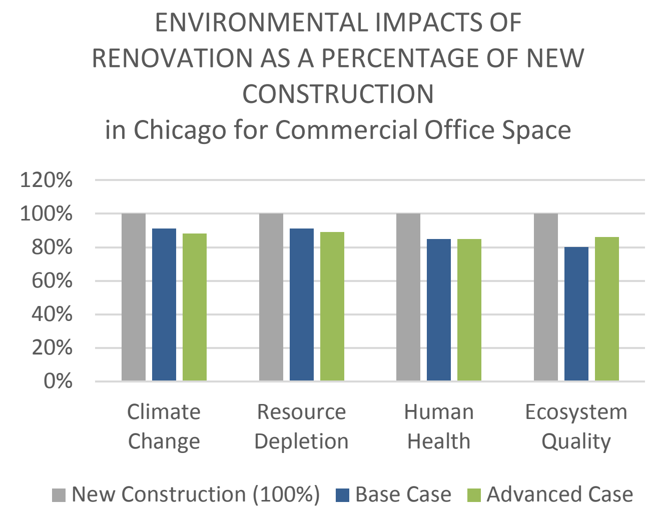


Chart 06 82-1
Base Case equals average energy performance.

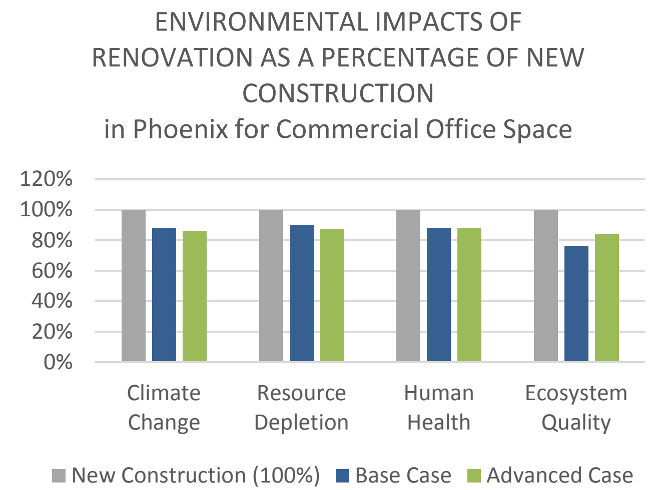


Chart 06 82-2
Advanced Case equals 30% more efficient than Base.

GENERAL NOTES continued:

- Fire Safety / Security Concerns need to be addressed in light of more stringent Guidelines.
- Poorly installed or maintained renovation projects in historic buildings can lead to moisture entrapment. Moisture entrapment is the critical issue when discussing insulation on historic buildings, especially wood structures. Moisture entrapment can not only lead to mold growth but to the rotting of the wood structure itself, causing irreparable damage. (National Trust for Historic Preservation, "PreservationNation," 2014).
- It is likely that whatever material is removed will expose areas requiring maintenance or renovation work.

Figure 06 82-1

Figure 06 82-2

NOTE: The photos to the right are images of mold, rot and termite damage in a 30 year old structure that did not have proper exterior water drainage or proper barriers. Repair was extensive both on the interior and exterior. Such situations are even more critical with historic structures.

CONSIDERATIONS FOR EXPOSING WOOD STRUCTURE:

- **General Info:**
  - Wood Structure is assumed to mean timber beams and columns.
  - Aesthetics
    - Evidence-based design is an approach where an occupant's responses to a building's physical characteristics are analyzed and used to inform design choices of future projects. (WoodWORKS! et al., "Wood In Healthcare," 2012).
    - People respond positively to wood and enjoy the variety of appearances.
    - Wood, therefore, contributes to a higher indoor environment quality and greater satisfaction of the building occupant.
  - Acoustics (Lighthouse Sustainable Bldg Centre, "Wood Specification: Acoustics," 2011)
    - Wood is understood to be one of the most acoustically preferred materials.
    - Wood can have acoustically absorptive qualities and be quieter than steel or concrete structures.
  - Air Movement
    - Wood structures do not conduct air differently than steel frame buildings. However, air can be used to dry out wood if moisture infiltrates. It is critical to properly analyze the existing structure's performance to ensure that additional problems like moisture entrapment are not made with the renovation project.

- **Approach:**
  - Contemporary wiring needs for lighting, fire suppression
    - If a historic structure was covered during past renovations, many times it was because of the need to run wiring and piping for contemporary needs.
    - Conduits can be painted to match the wood color and run along timber beams in the roof. Lighting can be strategically placed to cast the conduits in shadow, making them even less obvious to the building occupant while still meeting lighting, electrical and fire safety needs.
  - Take care when exposing any historic material to not damage it during the process.
  - If a wood member needs to be removed for additional maintenance work, ensure that it is properly marked and the location properly shored.

Figure 06 82-3

Figure 06 82-4 The wood ceiling was painted white while the columns and beams were exposed and left unpainted. The photos show the integration of modern lighting, HVAC, and fire safety with the historic wood.

CONSIDERATIONS FOR EXPOSING WOOD STRUCTURE continued:

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - Exposing the original, character defining structure and interior finish does not have any negative Historic Preservation Effects.

- **Energy Savings Potential**
  - Nothing is added to make the building more energy efficient in this Guideline.
  - Energy Savings comes from the simple fact that a new structure does not have to be built and the existing one can be made more desirable to the building occupant.
  - This Guideline should be used in conjunction with Guideline 06 81 Insulating Wood Structures and its related Guidelines, which has detailed energy savings potential information.

- **Cost Considerations**
  - Additional costs might be incurred from unforeseen conditions, problems that are exposed only after work has begun. There is no way to predict unforeseen conditions.
  - While working on a historic building, it is always important to hire contractors with historic building experience, in this case, historic wood building experience.
  - Selective demolition, as required when exposing wood beneath, can be more expensive than wholesale demolition of an entire building. However, the costs of new construction are avoided.

NOTE: Even when the existing historic structure is being used for a different purpose, it is possible to incorporate the historic structure into the contemporary space while still meeting energy efficiency, technological and security goals.

Figure 06 82-5

Figure 06 82-6

GUIDELINE DESCRIPTION:
This Guideline will discuss the issues of making the appropriate adjustments to a historic structure related to the new addition of roofing insulation. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 07 31 Insulation for Sloped Roofs, review for attic insulation and specific techniques.
- 07 51 Insulation for Flat Roofs, review for specific techniques.

GENERAL NOTES:
Consider the uniqueness of the building:

- the characteristics of its materials
- the climate of its location
- the specific construction methods that were used in its construction

Improperly adding insulation to a building can potentially damage on its overall energy performance. One can (perhaps unknowingly) do irreparable damage to historic features by adding insulation where it is not needed, inappropriate, or ineffective. Many older and historic buildings were not designed with insulation, so it requires great care to select compatible insulating systems and materials. See Guideline 07 21 Thermal Insulation.

"Older buildings, or those built before modern HVAC systems existed, were actually built to deal with the movement of air naturally through certain design features. If the building was constructed before 1950, careful consideration will need to be given before upgrading insulation. All systems – new and old – need to work in harmony." (National Trust for Historic Preservation 2012).

Roof Detailing varies from building to building from climate to climate.

3. ______

2. ______

1.

Figure 07 01-1 Numbers reflect different additions and renovations that can be seen in the cornice detailing and brick color.
Cambridge City Hall Annex, Cambridge, MA

Figure 07 01-2 Tower and decorative parapets are just a couple of the unique details on this Historic Building.
Old Airport Terminal Building, Albuquerque, NM

GENERAL NOTES continued:

Consider the shape of the building's roof to narrow down the options:

- sloped
- flat
- combination

In addition to a roof's shape, the elements and details found on a historic roof significantly contribute to its design. Some of the most commonly found roof elements and details include:

- cornices
- parapets
- coping
- pent house roofs
- eaves
- dormers
- towers
- chimneys
- finials
- cresting
- gutters and downspouts

In addition to the shape, elements and repetitive details, the materials used to cover sloping roofs are important to defining the character of a historic building because of the visibility of that feature. The most commonly found sloping roof materials are:

- metal
- slate
- clay tile
- asphalt shingles
- wood shingles
- wood shakes

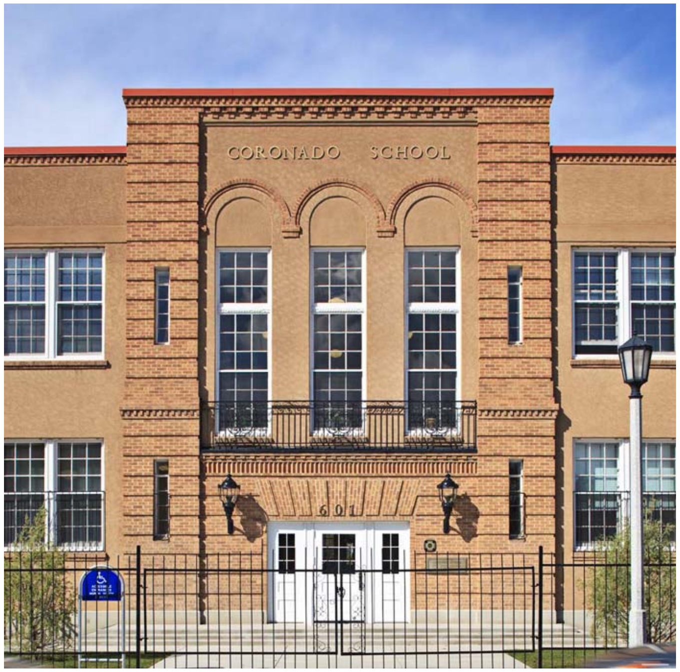


Figure 07 01-3 Historic Flat Roof, Coronado School, Albuquerque, NM

Figure 07 01-4 Historic Sloped Roof, 46 Blackstone, Cambridge, MA

GENERAL NOTES continued:

On the other hand, the appearances of materials used to cover flat roofs are usually not character defining because of their lack of visibility from the ground. They include:

- built-up roofing
- rubber roofing

Insulation can be installed in the attic space or in the roof structure. The least obtrusive method of adding insulation is in the attic space, this allows existing roof features and finish materials to remain intact and untouched. Guideline 07 31 Insulation for Sloped Roofs discusses this approach more in depth.

When adding insulation to the roof structure, exterior features or materials may need to be removed or replaced. Insulation adds thickness to the roof structure and may raise the overall appearance of the roof and change the relationship between the roof, overhangs, walls and parapets. This method should be a last resort and should be discussed with CRM/SHPO prior to design.

In addition, adding insulation may cause roof materials to deteriorate if it is not properly installed. This concern pertains to the 'breathing' aspect of the historic materials.

CONSIDERATIONS FOR ADDING INSULATION TO A ROOF:

- Ensure that the intervention or loss of historic fabric is kept to an absolute minimum.
- Time renovations to when routine roof maintenance is already required to pose the least impact to the roof and existing structure.
- Make sure that the structural performance of the roof will not be adversely affected.
- Be confident that the traditional 'breathing' performance of the roof is maintained, or reinstated. Take time to carefully select the materials and methods to be used, to ensure that they are compatible with traditional performance requirements. This concern usually means that the materials and 'systems' need to be vapor permeable.
- Any increased height of roof surface will impact roof drainage details. Be aware of these impacts and discuss with CRM/SHPO.

Common Historic Roofing Materials: (Top to Bottom)
Metal, Slate, Clay tile, Wood, Built-up, Rubber

Figure 07 01-5

Figure 07 01-6

Figure 07 01-7

CONSIDERATIONS FOR ADDING INSULATION TO A ROOF continued:

See Guideline 07 31 for warm and cold roof conditions. Determine whether the building has a:

- "warm roof" _ has insulation between or just under or over the sloping rafters, the whole volume under the roof can be heated and used.
- "cold roof" - a pitched roof with insulation at the level of the horizontal ceiling of the uppermost floor, leaving an unheated roof space (attic or loft) above the insulation.
- combination of the two

CONSIDERATIONS FOR REMOVING, REPLACING AND RAISING THE ROOF FEATURES:

- **Approach:**
  - A potential significant change; must confer with CRM/SHPO about the changes.
  - When a rehabilitation/renovation project requires that the roof features be raised to allow for insulation installation, the following items may be affected:
    - Cornices, Finials, Cresting, gutters and downspouts and roofing materials in general
  - Photograph existing conditions
  - Remove, number, and store existing feature. Keep good records of numbered items, photos and original locations.
  - Reinstall existing features.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 6: Repair of Deteriorated Historic Features
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - **If the existing roof is in good condition, do not disturb it and find other options; or delay changes until reroofing is needed.**
  - Consult with the CRM/SHPO before design work begins. Elevations may be affected and changes will need approval (presumably all the buildings being dealt with are listed).
  - Existing removed roofing materials, such as original slate shingles, may be required to be numbered and reinstalled in the same manner they were originally installed.
  - Parapet changes often change roof drainage affecting scuppers, downspouts, etc.

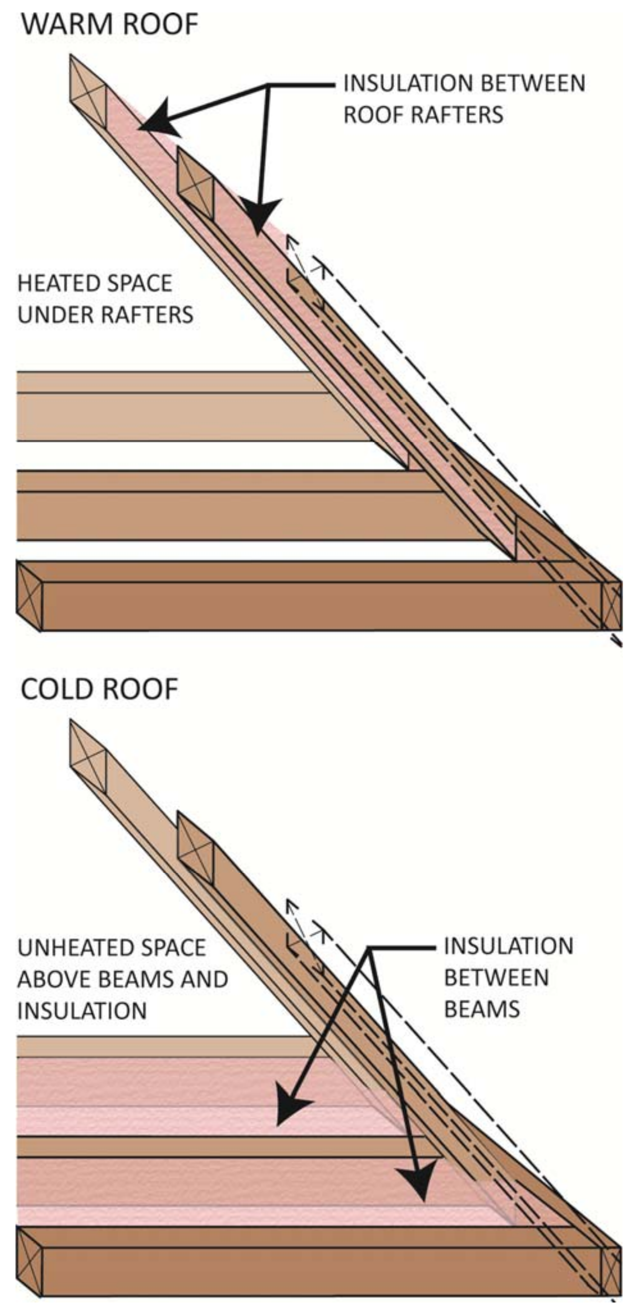


Figure 07 01-8

CONSIDERATION FOR REMOVING, REPLACING AND RAISING THE ROOF FEATURES continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Adding roof insulation, depending on the depth of the insulation added, will save energy accordingly.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - Exterior Roofing Material ______________
      - Vapor Retarder (if used) ______________
      - Wood Framing (rafters & beams) ______________
      - Insulation Material ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Extremely expensive option.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)**- ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

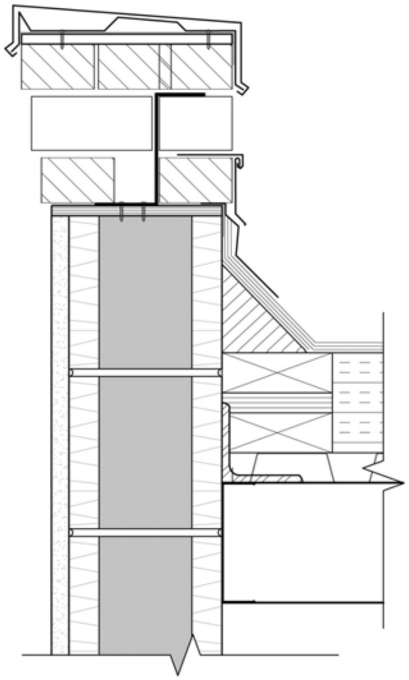
CONSIDERATIONS FOR RAISING THE PARAPETS FOR INSULATION:

- **Approach:**
  - Receive CRM/SHPO review and comment prior to making a change.
  - When a rehabilitation/renovation project requires that the parapets be raised to allow for additional thickness for insulation installation, the following items may be affected:
    - Coping, eaves, gutters and downspouts
  - Photograph existing conditions.
  - New height of building must remain in scale to surrounding environment.
  - Replace existing features.
  - Should only be considered if there is another reason to raise the parapet in addition to adding insulation.
    - For example: A new elevator penthouse is required and raising the parapet will help shield the penthouse from view at the street level.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Increasing parapet height due to increased insulation should be avoided if it is possible to add insulation without such changes.
  - A change in building elevations can alter the entire character of a building. Changing the dimensions of the façade requires prior review and comment by the SHPO.
  - Parapet changes often require roof drainage changes that can affect historic scuppers, downspouts, etc.
  - Where new parapet caps are required, profile and color of the material must be very carefully selected to be compatible with the existing materials. Consultation with the CRM/SHPO staff is recommended.

Figure 07 01-9



Construction Detail of the parapet condition shown above. Photo does not show the reconstructed brick detailing.

Coronado School, Albuquerque, NM

Figure 07 01-10

CONSIDERATION FOR RAISING THE PARAPETS FOR INSULATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Adding roof insulation, depending on the depth of the insulation added, will save energy accordingly.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - Exterior Roofing Material ______________
      - Vapor Retarder (if used) ______________
      - Roof Framing (rafters & beams) ______________
      - Insulation Material ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This Guideline will provide a general discussion of insulation and will cross reference to the other materials where insulation is discussed. It will provide a general discussion on what insulation can provide for a building, insulation value, and additional information with energy savings data. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, for specific information on insulating concrete walls
- 04 21 Insulating Masonry Walls, for specific information on insulating masonry walls
- 06 81 Insulating Wood Structures, for specific information on insulating wood structures
- 07 01 Adjusting Historic Features, for new insulation on roofs for discussion related to the unique conditions found on historic roofs
- 07 31 Insulation for Sloped Roofs, for information on insulating attic spaces
- 07 51 Insulation for Flat Roofs, for specific flat roof applications
- 07 92 Joint Sealants, for information on sealing before insulation

GENERAL NOTES:

- Part one of this Guideline assumes that insulation is being considered.
- Part two of this Guideline discusses which insulation to install.
    - Perform an energy audit or have a qualified energy assessment performed to identify areas of the building that are in need of energy loss reduction.
    - Verify if the building already has insulation, how much (R-value and thickness) and where
- For the Historic Preservation Effects: See applicable sections in the Related Guidelines.

Air Escape Routes in a Building

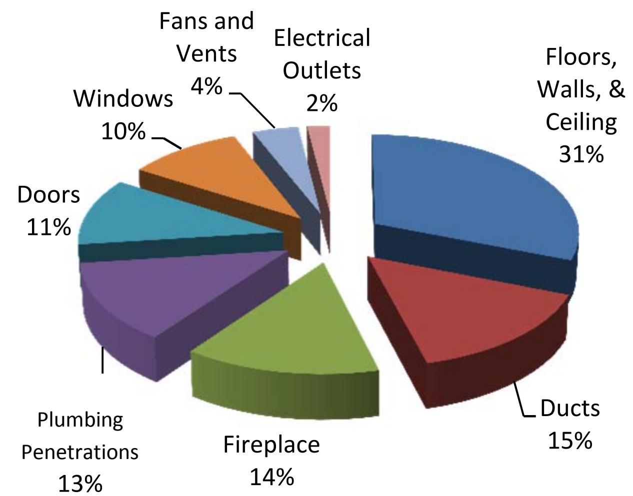


Chart 07 21-1
Energy Savers Data, U.S. Department of Energy

PART 1: PRIOR TO INSULATION

1. **Perform an Energy Audit.** For more information see 00 01 Project Organization on page 13.

2. **Check and Fix Seals and Weatherstripping.** For more information, see Guideline 07 92 Using New Joint sealants on Historic Components on page 146.

3. **Improve existing systems.**
   - Regularly clean and service furnace / boiler
   - Regularly change air filters or drain the rusty sludge from boilers
   - Insulate distribution lines (ductwork or steam pipes)
   - Ensure that registers and radiators are not blocked by curtains or furniture

4. **Address Moisture Issues.**
   - Insulation can exacerbate moisture issues
     - Many buildings were designed with the knowledge that moisture would enter.
     - Insulation can entrap moisture by absorbing it or sealing the flow of air that dried it.
       - Entrapped moisture can cause wood to Rot, Pop mortar / grout joints, Corrode steel, and Foster mold growth
   - **Moisture**: Old walls were designed to allow air movement through the wall to dry moisture that seeped in. Therefore, one MUST conduct careful analysis of wall assembly to determine the extent of any moisture/ventilation conditions.
     - Building specific since many factors influence
       - Climate & microclimates (one side shaded, etc), Building geometry, Ease of air flow, Condition of building materials, Construction details, Etc…
     - Most of the United States is in a heating/cold climate which means that the most appropriate location for insulation is on the exterior wall face. Preservation dictates that insulation can only (typically) go on the inside face of the exterior wall, if at all.
     - Insulation typically reduces air infiltration which helps dry out moisture in the walls. Reducing air infiltration increases interior comfort but can cause more freeze/thaw stress issues within the cavity. This can lead to MOISTURE ENTRAPMENT.
   - **Basics:** Moisture in relatively warm air will condense on a cooler surface. It can then run down and moisten materials it touches.

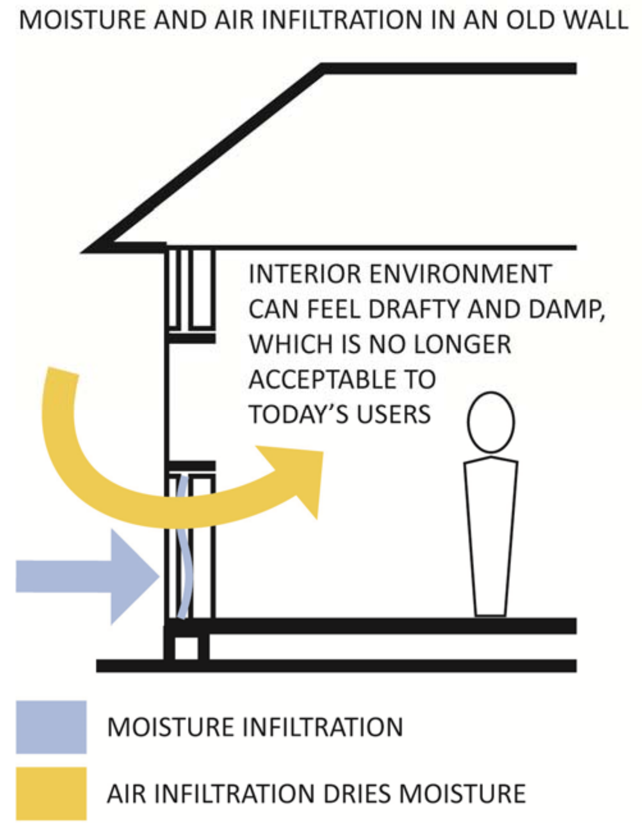
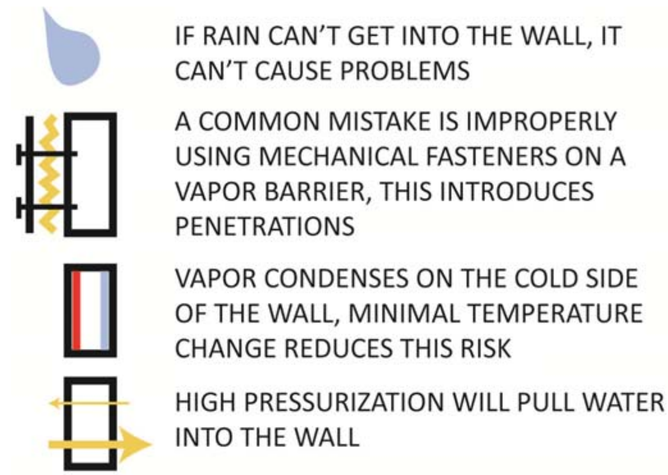


Figure 07 21-1

PART 1: PRIOR TO INSULATION continued

4. **Address Moisture Issues continued**.
   - **Moisture Entrapment**: In a study on solid masonry walls conducted by the Canada Mortgage and Housing Corporation, computer modeling showed increased condensation but visual observations did not show significant damage attributable to the retrofit.
     - The preliminary/short term results show that insulating solid masonry walls does not appear to deteriorate the exterior solid masonry wall when the retrofit approach involves the installation of a suitable air and vapor barrier.
     - While conditions for freeze-thaw action may be present, this action may not be sufficient to damage the masonry assembly.
     - An air-space behind the exterior masonry on the cold side of the new air barrier is beneficial: to reduce the rate of diffusion condensation, to provide improved drainage in pressure equalized walls, to reduce moisture entrapment, and to improve the drying rate of the exterior masonry through convection and air travel.
   - **Minimizing Moisture Issues:** Aimed to help control humidity attacking the wall assembly
     - **Minimize rain penetration into the wall assembly**
     - **Provide a continuous vapor barrier within the wall assembly to minimize interior moisture getting into the assembly.**
       - Location of the barrier depends on several factors: wall materials, their order of installation, the temperature and relative humidity conditions maintained.
     - **Minimize the temperature drop within the wall assembly:**
       - Balance between objectives of durability, thermal performance and comfort.
     - **Minimize the air pressure differential across the exterior wall assembly:**
       - Balance mechanical systems so a relatively neutral air pressure exists.



5. **Before adding insulation consider:**
   - Has attic and basement insulation already been done?
   - Can energy savings be achieved another way?
   - Can insulation be added without causing significant loss of historic material or deterioration of the wall assembly?
   - Will it be cost effective?

PART 2: DETERMINING WHICH INSULATION TO USE AND WHERE IT SHOULD BE LOCATED

1. Most people automatically assume insulation in walls first. However, in historic structures, walls should be the last place to add insulation because of the difficulty and cost of the installation, and the risk it poses to historic elements. Consider Attics and Basements/Crawlspaces first as these spaces tend to be uninhabited, service spaces.
2. **Attics:** These are great places to insulate because the historic materials found in attics are not typically character defining, and the spaces are not regularly inhabited. See Guideline 07 31 Insulating Sloped Roof for specific information on insulating attic spaces.
3. **Basements/Crawlspaces:** Like attics, these are also great places to insulate. See Guidelines 03 31 Insulating Concrete Walls and 04 21 Insulating Masonry Walls for more specific information.
4. **Walls**: Not recommended for many reasons, can be very difficult and expensive
   - Exterior wall insulation is rarely, if ever, appropriate for historic buildings because:
     - Likelihood of damage to the exterior finishes.
     - Increased thickness changes relationship of wall to roof, windows, eaves, thus compromising the architectural integrity and appearance, interferes with details, etc
   - Insulation in general is not recommended by the National Trust unless for a major rehab
     - Destroys historic detailing if surfaces need to be removed to add the insulation.
       - National Trust states that with historically-significant interiors, adding insulation poses too high of a risk to the historic aspects (ie cornices), moisture intrusion with insufficient energy savings.
     - Non-original, non-significant materials can hinder application, too, if they have been applied overtop of historic materials.(Walls and Foundations of Historic Buildings, 9)
       - Will removal further damage the historic material beneath?
       - Is the added risk, cost of removal and probable repair of underlying material worth the increased efficiency?
   - Covering an original wall is almost never appropriate
   - If non-original material already exists and should not be removed, and is not significant in itself, it may be appropriate to cover it – as long as the new material is compatible with the wall assembly.

Figure 07 21-2

PART 2: DETERMINING WHICH INSULATION TO USE AND WHERE IT SHOULD BE LOCATED continued

4. **Walls continued:**
   - As previously stated in Part 1 page 56, conduct a careful analysis of wall assembly, especially regarding possible moisture/ventilation issues.
     - Determine the type of construction
       - Wood
       - Masonry: Solid, Cavity, Early cavity (tied with brick/masonry leaves, no insulation, unpredictable cavity depth, not easy to discover)
     - Determine Dampness – walls that have been wet for years can take years to dry out
     - Try to determine the movement of heat and water. This is very difficult to assess because data is not available and models reflect idealized situations.
     - Determine the hardness of materials
       - Lime-based mortars are softer and “breath” more than cement based products
     - Determine the Thermal Mass if any
     - Determine if there is any wildlife and if it is a protected species. Birds/bats can make homes in cavity walls.

5. Determine the Amount of Historic Material on the building:
   - The greater the retrofit and the more historic material that needs to be replaced for other reasons provide more available options for insulation. The key is to find the balance between preservation, increased energy efficiency and cost.
   - Non-significant interiors do allow for more insulation options.

6. Location of mechanical equipment is an important consideration when determining the thermal envelope, i.e. the location of the insulation
   - Mechanical equipment should be in the thermal envelope of the building, if possible.

7. Some states have specific requirements regarding insulation. Work with local CRM/SHPO to determine what meets preservation goals and energy goals, and is best for the specific bldg. (Building Energy Codes Program: Status of State Energy Code Adoption 2012).

Resources:
All SHPO: http://www.nps.gov/nr/shpolist.htm

SHPO Inventories of Historic Places on the Web
http://www.cr.nps.gov/nr/shpoinventories.htm

National Park Service provides additional useful links:http://www.cr.nps.gov/nr/preservation_links.htm#shpo

Insulation Basics :
http://www.ornl.gov/sci/roofs+walls/insulation/ins_01.html

Insulation Guides:
http://www.climatechangeandyourhome.org.uk/live/saving_energy_in_buildings_intro.aspx

Holding the Line: Controlling Unwanted Moisture in Historic Buildings NPS Brief 39:
http://www.nps.gov/history/hps/TPS/briefs/brief39.htm

Additional Wall Insulation Information:
http://www.oldhouseweb.com/blog/adding-wall-insulation/

GUIDELINE DESCRIPTION: This Guideline will explore the different sloped roofing exterior materials. It will discuss the design/technology of the historic roofing systems and how insulation can be applied. It will also look at adding insulation in the horizontal plane of the attic area and discuss pros and cons of insulating or not insulating the entire interior space. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 01 Adjusting Historic Features, for new insulation on roofs
- 07 21 Thermal Insulation, for basic considerations on insulating historic buildings
- 07 51 Insulation for Flat Roofs, for issues related to flat roofs
- 07 92 Joint Sealants, for sealing joints in roof and other building features
- 23 12 HVAC Exterior Placement, for rooftop and attic equipment considerations

GENERAL NOTES:

- Historic, free-standing buildings often have sloped roofs which vary in shape:
    - Gable
    - Hipped
    - Cross Gable
    - Mansard
    - Gambrel
    - Shed
- Design Technology of Historic Roofing Materials: In many older buildings, the original architects designed the roof structure with liberal slope for drainage. Typically, low-slope decks employing masonry or cementitious materials were protected by built-up coverings or sheet metal. A common practice on low slopes was to use an organic felt bituminous-membrane system adhered directly to the deck, without rigid insulation. In our research – and depending on the age of the structure – it is not unusual to discover several membrane layers applied one over the other, sometimes with rigid insulation installed between some of the layers, as well. Also, older building designs often include attic spaces, providing access to mechanical, plumbing, and electrical services.

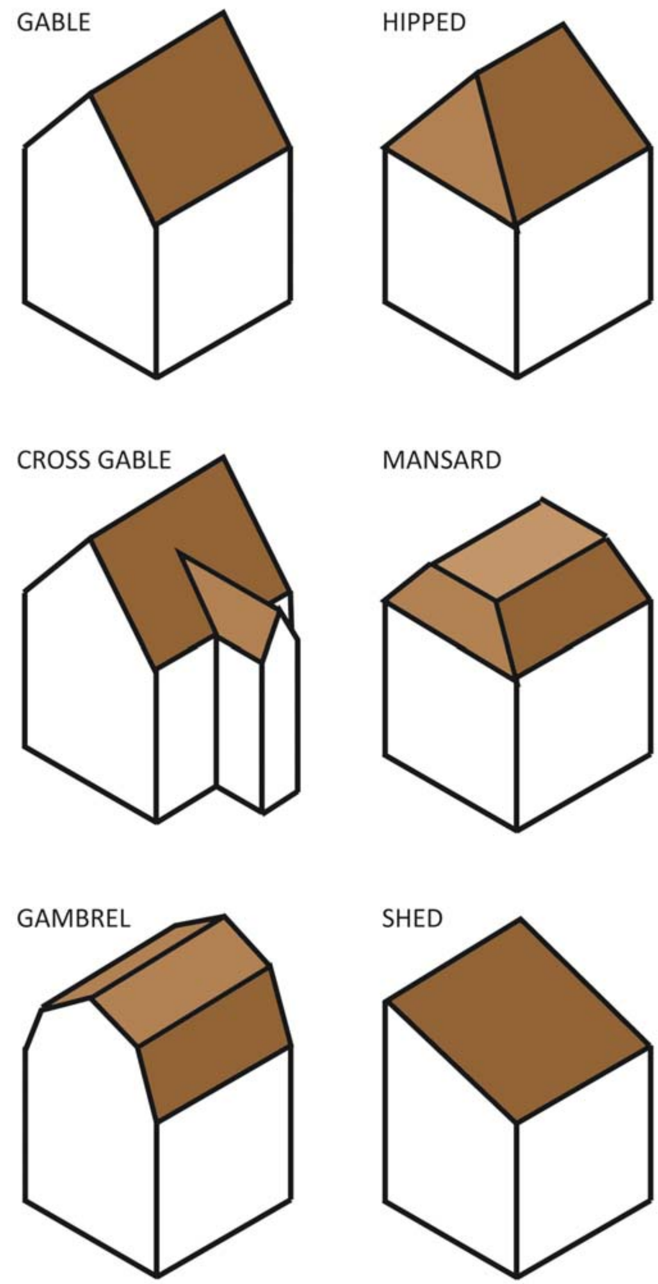


Figure 07 31-1

GENERAL NOTES continued:

- Roof Insulation Applications:
  - First choice – in the attic
  - Second choice – in the roof assembly, being careful with removal and replacement of historic roofing materials.
  - The addition of insulation to the roof assembly may be desired, but it may not be necessary if an attic space exists. Insulating the attic rather than the roof system is a more viable option in order to meet energy code requirements. Insulation can also be used in the roof assembly where the substrate is uneven and irregular to provide a smooth, uniform surface for the roof membrane.
- Roofs are insulated to reduce energy consumption. The location of roof insulation when installed in the attic space rarely affects the appearance of a building and thus will usually not alter its character. However, adding insulation may cause roof materials to deteriorate if it is not properly installed.

GENERAL CONSIDERATIONS:

- Ensure that the intervention or loss of historic fabric is kept to an absolute minimum.
- Make sure that the structural performance of the roof will not be adversely affected.
- Be confident that the traditional 'breathing' performance of the roof is maintained, or reinstated. Take time to carefully select the materials and methods to be used, to ensure that they are compatible with traditional performance requirements. This consideration usually means that the materials and 'systems' need to be vapor permeable.
- Determine whether the building has either a:
  - "cold roof" - a pitched roof with insulation at the level of the horizontal ceiling of the uppermost floor, leaving an unheated roof space (attic or loft) above the insulation.
  - "warm roof" – has insulation between or just under or over the sloping rafters, the whole volume under the roof can be heated and used.
  - combination of the two

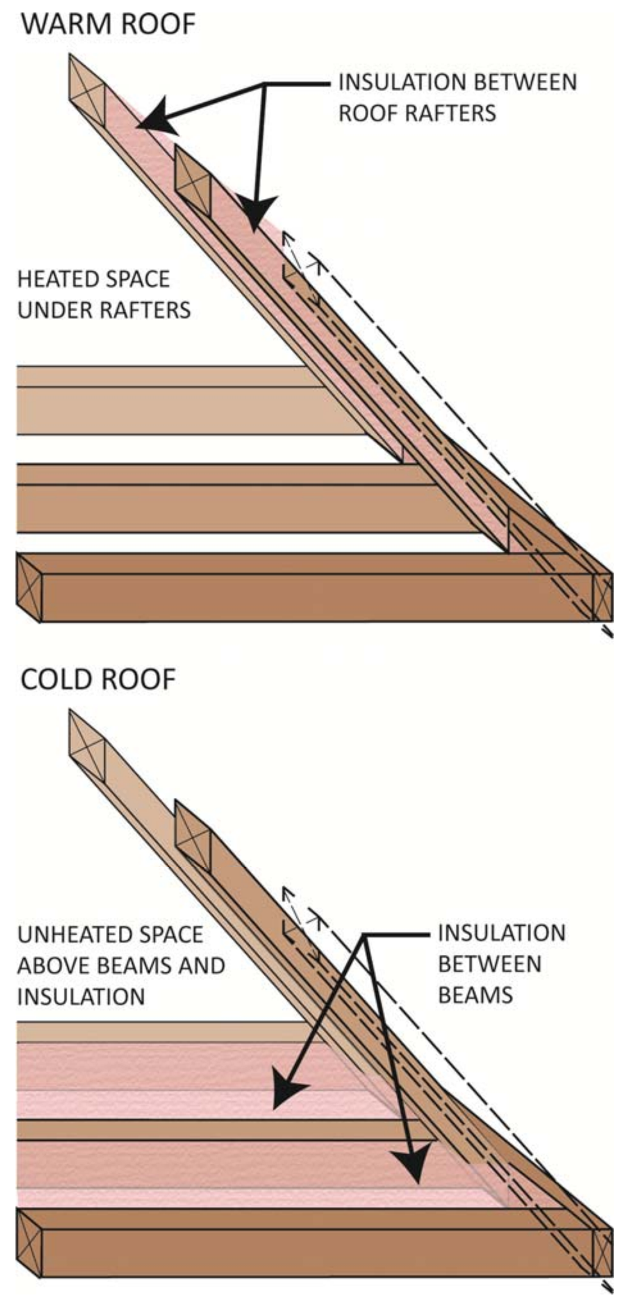


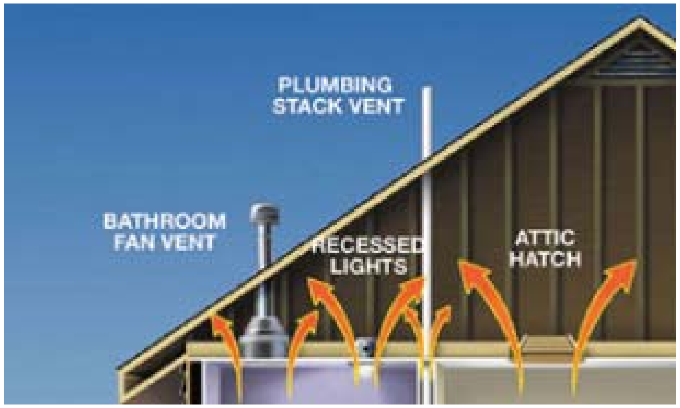
Figure 07 31-2

CONSIDERATIONS FOR INSTALLING ATTIC INSULATION OR COLD ROOF APPLICATION:

Attics are great places to insulate because the historic materials found in them are not typically character defining, and the spaces are not regularly inhabited.

- **Approach:** This Guideline assumes that all attics are of similar construction, typically timber-framed (or steel frames with the newest buildings becoming eligible).
  - Insulating attics is preferable to insulating roof deck which contain a larger envelope and more difficult installation, but might consider roof deck if mechanical equipment is housed in the attic. (Hensley and Aguilar n.d., 8).
  - In the vented attic of older buildings insulation goes between the ceiling joists. Make sure that the insulation does not incorporate any vapor barrier or paper facing. The insulation should be prevented from getting dirty as this reduces its effectiveness.
  - Before installing any type of insulation in an attic, follow the steps outlined in Part 1 of Guideline 07 21 Thermal Insulation and those that follow below.
  - Seal all attic-to-living/working space air leaks.
    - Duct exhaust fans to the outside. Use a tightly constructed box to cover fan housing on attic side. Seal around the duct where it exits the box. Seal the perimeter of the box to the drywall on attic side.
    - Cover openings—such as dropped ceilings, soffits, and bulkheads—into attic area with plywood and seal to the attic side of the ceiling.
    - Seal around chimney and framing with a high-temperature caulk or furnace cement.
    - At the tops of interior walls, use long-life caulk to seal the smaller gaps and holes. Use expanding foam or strips of rigid foam board insulation for the larger gaps.
  - Install blocking (metal flashing) to maintain fire-safety clearance requirements for heat-producing equipment found in an attic, such as flues, chimneys, exhaust fans, and light housings/fixtures unless the light fixtures are IC (insulation contact) rated. IC-rated lights are airtight and can be covered with insulation.
  - Make sure insulation does not block soffit vents to allow for attic ventilation.
  - Check the attic ceiling for water stains or marks. They indicate roof leaks or lack of ventilation required to dry moisture intrusion. Make repairs before insulating. Wet insulation is ineffective and can damage the building.
  - Insulate and air seal the attic access if it is located in a conditioned part of the building.

(Heated) Air Leaking out of a building



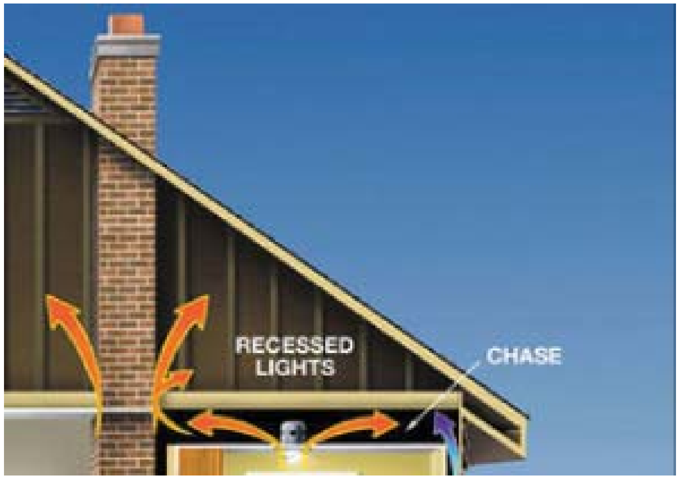


Figure 07 31-3
Graphics Courtesy of the U.S. Department of Energy

CONSIDERATIONS FOR INSTALLING ATTIC INSULATION OR COLD ROOF APPLICATION cont.:

- **Approach continued:**
  - **Types of Insulation:**
    - Rigid foam or batts common
      - Discuss use of vapor retarder with Design Team.
      - Possible to add new insulation over existing.
        - Use unfaced batts, placed perpendicular to old and over top of joists to reduce thermal bridging. (Hensley and Aguilar n.d., 7).
    - Open-cell spray foam only to be used when there are no gaps in roof sheathing
      - Permanent and Higher possibility that roof leaks could go undetected.
    - Use Blown-in where fiberglass batts can be difficult to install. (Lugano 1996).
      - Ensure proper preparation is taken prior to installation to minimize insulation getting into the wrong places or potentially causing a fire.
      - Use low pressure and speed on top of existing material to yield higher R-values.
  - **REMEDIATION** of existing insulation: Vermiculite and perlite insulation materials are common in attic insulation installed before 1950. Vermiculite insulation materials sometimes contain asbestos. However, asbestos is not intrinsic to vermiculite. (U.S. EPA 2012). If there is vermiculite insulation in the attic, do not disturb it. Have it tested for asbestos content by a reputable hazardous material testing company.
    - Sequence for remediation:
      1. Test insulation material
      2. If asbestos is present – have a professional prepare a removal specification
      3. Abatement conducted by professional hazardous material removal service
      4. Regular insulation contractor to proceed with new insulation installation
- **Applicable Secretary of the Interior Standards**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
- **Historic Preservation Effects**
  - No adverse effects, however, spray foam generally has an adverse effect because it is not reversible. The easiest and least intrusive installation method is adding batts between the ceiling joists. It can be easily removed without damage to the building.

Figure 07 31-4
Fiberglass Batts: Insulation still needs to be added perpendicular to the joists to reduce thermal bridging.

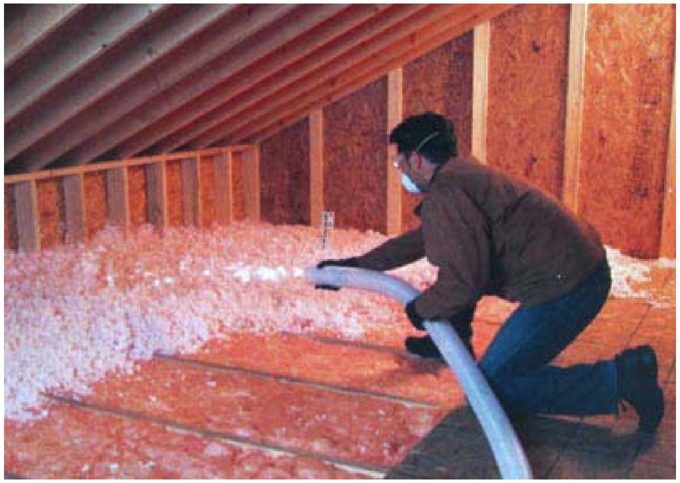


Figure 07 31-5
Blown in Insulation Installation

CONSIDERATIONS FOR INSTALLING ATTIC INSULATION OR COLD ROOF APPLICATION cont.:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - Adding insulation in an area that had little to no insulation will only benefit the building's energy savings. The savings potential will be dependent on:
    - Whether the attic was air-sealed properly
    - The amount of new insulation installed
    - The R-value of the insulation installed
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - Exterior Roofing Material ______________
      - Vapor Retarder (if used) ______________
      - Roof Framing (rafters & beams) ______________
      - Insulation Material ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Loose-fill or batt insulation is typically installed in an attic. Installation costs may vary, loose-fill insulation is usually less expensive to install than batt insulation. When installed properly, loose-fill insulation also usually provides better coverage.
    - Typically, a low cost, highly effective retrofit.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR A WARM ROOF:

- **Approach:** If the attic is not vented, the easiest solution is to use a radiant barrier over the attic rafters. This will prevent 95 percent of the heat from the roof from coming into the attic in the summer. Make sure that the radiant barrier has an air space between the material and the underside of the roof.
  - A radiant barrier is highly reflective sheet/coating (aluminum) applied to one or both sides of a flexible material.
    - Foil surface faces an air space.
  - A radiant barrier's effectiveness depends on proper installation. Therefore, it is best to have a certified installer do it.
  - It is NOT recommended for the radiant barrier to be installed on top of attic floor insulation. It will be more susceptible to dust accumulation and trap moisture on the underside.
  - Radiant barriers – in lieu of insulation, "to reduce thermal radiation across the air space between the roof deck and attic floor in order to reduce summer heat gain" (Hensley and Aguilar n.d., 8).

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects**
  - Because mechanical attachment to rafters is necessary, it will take minor effort to remove and fill holes if required to remove radiant barrier.
  - If historic roofing is not salvageable, the radiant barrier can be installed before new roofing is installed.

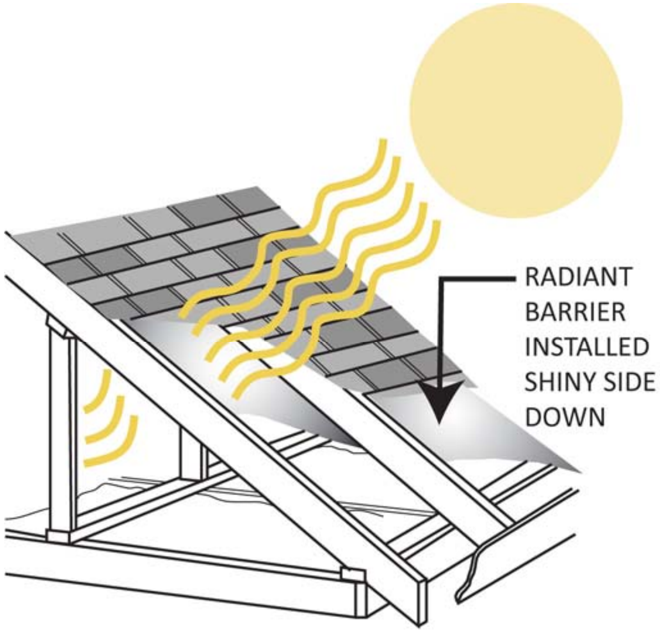


Figure 07 31-6

Figure 07 31-7

CONSIDERATIONS FOR A WARM ROOF continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Adding a radiant barrier in an area that has little to no insulation will only benefit the building's energy savings. The savings potential will be dependent on:
    - Climate – radiant barriers can be used in hot climates to reduce cooling loads.
    - Reflectivity of surface – barriers are only effective if the surface remains reflective.
    - Placement – do not use against insulation, as it can act as vapor barrier.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - Exterior Roofing Material ______________
      - Vapor Retarder (if used) ______________
      - Roof Framing (rafters & beams) ______________
      - Insulation Material ______________
      - Radiant Barrier ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Radiant Barrier and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This Guideline will discuss the re-roofing of flat roofs and adding rigid tapered insulation on top of the roof deck, and using different color roofing materials while providing appropriate drainage. It will also discuss applying insulation to the underside of the roof and the pros and cons to this method. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:
- 07 01 Adjusting Historic Features, for new insulation on roofs
- 07 21 Thermal Insulation, for general insulation information
- 07 51 Insulation for Sloped Roofs, for similar concepts
- 07 92 Joint Sealants, for how to seal roof penetrations
- 23 12 HVAC Exterior Placement, for roof top equipment considerations

GENERAL NOTES:
- The term flat roof is somewhat misleading. Flat roofs are rarely absolutely flat, they usually slope toward the rear of the building to drain water. Since a flat roof is typically not visible from the ground, its design does not normally contribute to the character of the building. However, the cornice, parapet, pent house roof or other feature at the edges of a flat roof are often visible, potentially, contributing to the character of a building.
- The materials used to cover flat roofs are usually not character defining. They include:
  - built-up roofing
  - rubber / membrane roofing
- An Owner can increase the energy efficiency of a flat roof system by:
  - Adding insulation and increasing R-value
  - Applying the insulation in a more efficient manner (seams staggered or “screw and mop”)
- The location of roof insulation on a flat roof rarely affects the appearance of a building. However, adding insulation may cause roof elements to be raised higher than their original location, and additional height can impact façade proportions, drainage features and other façade details. See more under Guideline 07 01 Adjusting Historic Features for New Insulation on Roofs.

Figure 07 51-1
New insulation and built-up roof applied to historic Coronado School, Albuquerque, New Mexico.

CONSIDERATIONS FOR NEW FLAT ROOFS (WARM ROOF):

- **Approach:**
  - Often it will be easier and less damaging to remove roof coverings to upgrade a roof than to take down and replace historically significant ceilings. The installation of insulation above the decking will require the roof to be raised externally to accommodate proper drainage, which may or may not be acceptable. This installation above the decking and below the waterproof layer is called the 'warm deck' system.

    Basic Principle: Insulation placed above the structural deck and beneath the waterproof layer (warm roof construction) reduces the risk of condensation but, because the waterproof layer is thermally isolated from the rest of the roof construction, it is exposed to wide temperature fluctuations with consequent increased risk of premature failure.

- **Applicable Secretary of the Interior Standards**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects**
  - By adding insulation to the roof system, the required thickness of insulation may require the roof elevation to be raised, thus affecting parapet heights and downspout heights. Discussion with the CRM/SHPO may be necessary to get the reviews and comments for these changes.
  - Historically significant ceilings can be preserved with this method.

WARM DECK ASSEMBLY

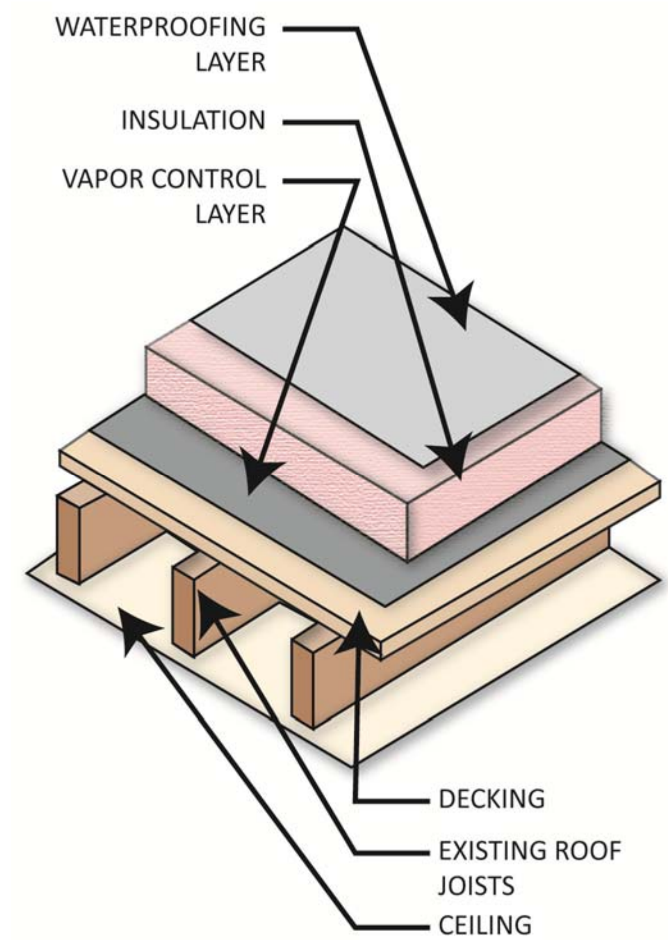


Figure 07 51-2

CONSIDERATIONS FOR NEW FLAT ROOFS (WARM ROOF) continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Depending on the height of parapets and downspouts, the amount of insulation installed can vary. Energy Savings Potential is high.
  - New roofing material can be incorporated because flat roofs are not visible from the ground. By using material with higher reflectance, less heat is absorbed, thus saving on cooling costs.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - New Exterior Roofing Material ______________
      - Vapor Retarder / Waterproofing ______________
      - Insulation Material ______________
      - Roof Framing (deck, joists and beams) ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - A Thermoplastic Polyolefin (TPO) membrane roof is the most cost effective.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

- **Other Considerations**
  - Care should always be taken not to force insulation down onto the ceiling from above because it can distort the ceiling surface.

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation, new roof and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR ADDING INSULATION ON A NEW FLAT ROOF (INVERTED WARM ROOF):

- **Approach:** Another option to the installation for a "Warm Roof" application is to install the insulation above the decking AND the waterproofing layer. This is called the 'inverted warm deck' system.

  Basic Principle: The inverted roof concept overcomes the problem by placing thermal insulation above the waterproof layer, maintaining it at an even temperature close to that of the building interior and protecting it from the damaging effects of UV radiation and from mechanical damage. The risk of condensation is eliminated.

- **Applicable Secretary of the Interior Standards**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects**
  - By adding insulation to the roof system, the thickness of insulation may require the roof elevation to be raised, thus affecting parapet heights and downspout heights. Discussion with the CRM/SHPO may be necessary to get the reviews and comments for these changes.
  - Ceilings can be preserved with this method.

INVERTED WARM DECK ASSEMBLY

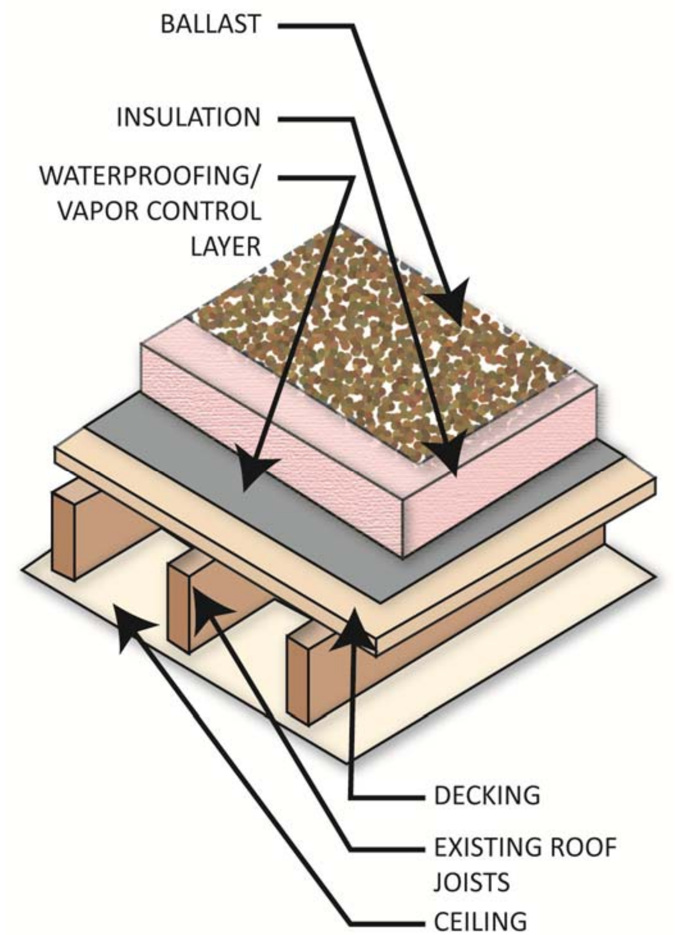


Figure 07 51-3

CONSIDERATIONS FOR ADDING INSULATION ON A NEW FLAT ROOF (INVERTED WARM ROOF) continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
    - Depending on the height of parapets and downspouts, the amount of insulation installed can vary. Energy Savings Potential is high.
    - New roofing material can be incorporated because flat roofs are not visible from the ground. The 'inverted warm deck' system usually works with a ballast roof system.
    - **Before using the online calculator or provided table, determine the following:**
        - **R-Values** for roof materials:
            - New Exterior Roofing Material ______________
            - Vapor Retarder / Waterproofing ______________
            - Insulation Material ______________
            - Roof Framing (deck, joists and beams) ______________
            - Interior Sheathing (sheet rock) ______________
    - **Assumptions** (both for the calculator and table)
        - That the roof is exposed to outside temperatures.
        - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
    - **Before using the online calculator or provided table, determine the following:**
        - **Heat Source** - ______________
        - **Cost** - ______________
        - **Location** - ______________
        - **Total Heating Degree Days (HDD)**- ______________
        - **Total Cooling Degree Days (CDD)** - ______________

- **Other Considerations**
    - Care should always be taken not to force insulation down onto the ceiling from above because it can distort the ceiling surface.

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation, new roof and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR ADDING INSULATION UNDER A NEW OR EXISTING FLAT ROOF:

- **Approach:**
  - Insulation within the roof construction can be installed below the decking and above the ceiling, called the 'cold deck' system,
  - Insulating with the 'cold deck system' is perhaps the most frequently used arrangement in historic buildings, but not necessarily the most appropriate. Ceilings need to be removed in order for the insulation to be installed.
  - **Basic Principle:** If insulation is placed below the structural deck (cold roof construction) the structure remains cold and there is a considerable risk of condensation; for that reason cold deck roofs are not recommended and are now seldom used.
  - Ensure that the intervention or loss of historic fabric is kept to an absolute minimum.
  - Make sure that the structural performance of the roof will not be adversely affected.
  - Take time to carefully select the materials and methods to be used, to ensure that they are compatible with traditional performance requirements - this usually means that the materials and 'systems' need to be vapor permeable.
  - Roof slope – adding thickness to a roof slope may affect the parapet heights.
  - Roof drainage – adding insulation creates new slopes to existing roof drains. Drains need to be raised in some cases.
  - U.L. Fire Classification Requirements
  - Repair vs. Replacement

- **Applicable Secretary of the Interior Standards**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects**
  - Ceilings need to be removed for this installation.
  - Sometimes it is discovered that the roof structure and/or roof deck, has been damaged and will need repair.
  - Maintain or reinstate the traditional 'breathing' performance of the roof.

COLD DECK ASSEMBLY

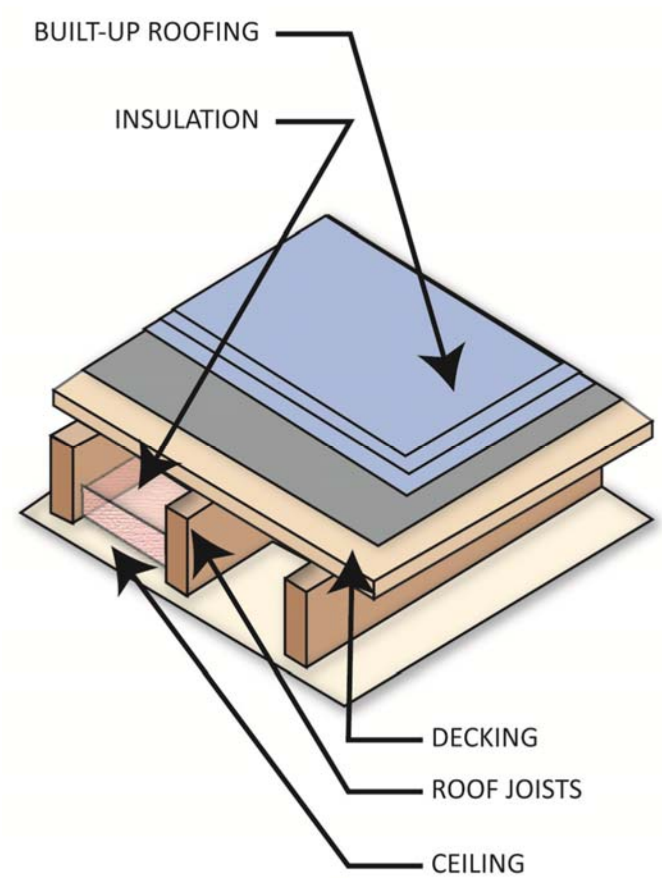


Figure 07 51-4

CONSIDERATIONS FOR ADDING INSULATION UNDER A NEW OR EXISTING FLAT ROOF continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - Adding any insulation into the roof system is an energy savings benefit. Just how much depends upon the roof structure space.
  - R-Value – verify the building code requirements for insulation R-values
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for roof materials:
      - New or Existing Exterior Roofing Material ______________
      - Vapor Retarder / Waterproofing ______________
      - Roof Framing (deck, joists and beams) ______________
      - Insulation Material ______________
      - Interior Sheathing (sheet rock) ______________
  - **Assumptions** (both for the calculator and table)
    - That the roof is exposed to outside temperatures.
    - That energy savings for all roofs are not dependent on building orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Can be more expensive depending on the ceiling type to replace.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Roof structure – ASHRAE Standard 90.1 2004*
- *Insulation, roof and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This Guideline will examine the considerations and potential energy saving achieved by installing a green roof on a historic building. This Guideline assumes that the historic structure does not currently have a green roof, nor did it at any point in the past. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 07 31 Insulation for Sloped Roofs
- 07 51 Insulation for Flat Roofs
- 26 01 Solar Photovoltaic Panels

GENERAL NOTES:

- A green roof is vegetation planted over a waterproofing system on top of a roof.
- One of the oldest forms of roofing systems, however modern technology differs greatly from the early forms.
  - Ancient forms were sod and plants and provided good insulation but no waterproofing.
  - Modern technology began in Germany in the 1970's and provided reliable irrigation and protection from root penetration into the waterproofing layer.
  - (Breuning, Jörg and Green Roof Service LLC 2014)

- The National Park Service defines green roofs as: Extensive, semi-intensive, and intensive.
  - Extensive – developed in the 1980's http://www.greenrooftechnology.com/extensive-green-roof
  - Characterized by the types of vegetation which require little maintenance and no permanent irrigation system.
    - Plant types: sedums, small grasses, flowering herbaceous plants
  - Growing medium is typically 6 inches or less
  - Ideal for storm water management, have low maintenance and can be integrated with PV/Solar systems.
  - Can be used on sloped roofs with proper design

Figure 07 52-1 Ancient Green Roof. Photo by Flidais Niafer.

Figure 07 52-2 Chicago City Hall, one of the most well-known examples of a modern green roof on a historic building. Photo by Mark Farina.

Figure 07 52-3 Extensive green roof

GENERAL NOTES continued:

- Semi-Intensive – http://www.greenrooftechnology.com/semi-intensive-green-roof
  - Characterized by moderate maintenance and occasional irrigation.
    - Plant types: small herbaceous plants, ground covers, grasses and small shrubs.
  - Growing medium is typically 6-12 inches.
  - Retains more storm water than extensive green roofs and can host a more diverse ecology. Semi-intensive systems can be developed into a formal garden effect.
- Intensive – Also known as Roof Gardens http://www.greenrooftechnology.com/intensive-green-roof
  - Characterized by professional maintenance and a permanent irrigation system.
    - Plant types: herbaceous plants to small trees.
  - Growing medium is 6 inches or more
  - Offer the greatest potential for biodiversity and design, including full scale parks.
- In addition to the energy savings, other benefits include:
  - Reduced air pollution and greenhouse gas emissions because of lower air conditioning demand. Vegetation can also remove pollutants and greenhouse gas emissions through dry deposition and carbon sequestration and storage.
  - Improved human health and comfort: reduced heat transfer through the building roof can improve indoor comfort and lower heat stress associated with heat waves.
- *Enhanced storm water management and water quality:* reduce and slow storm water runoff in the urban environment; they also filter pollutants from rainfall. (U.S. Environmental Protection Agency, "Heat Island Effect: Green Roofs," 2013).

Figure 07 52-4 Semi-Intensive Green Roof

Figure 07 52-5 Intensive Green Roof, Millennium Park, Chicago

CONSIDERATIONS FOR USING GREEN ROOFS ON HISTORIC BUILDINGS:

- **Approach:**
  - In many historic buildings, the designed roof loads are unknown, the building's structure was not likely designed to carry the weight of a green roof, and the established character defining features do not likely include a green roof. For these reasons, the only type of green roof system that should be considered for a historic building is an extensive system.
  - Even though extensive green roof systems can be installed on sloped roofs, the drastic change in visual appearance makes installation on a historic building a poor choice.

CONSIDERATIONS FOR USING GREEN ROOFS ON HISTORIC BUILDINGS continued:

- **Approach continued:**
  - Careful analysis of the existing structure is critical to a successful installation and the longevity of a green roof system.
    - Know the structural loading capacity, existing roofing materials, drainage system, waterproofing, environmental exposure, and electrical and water supply in place.
    - Also consider who will have access to the roof and who will do maintenance.
  - Components of an extensive green roof system include:
    - **Drainage:** must both maintain growing conditions in the growth medium and manage heavy rainfall without sustaining damage.
    - **Plant nourishment and support:** The engineered medium must be designed for excellent plant growth, no wind scouring, and proper water holding capacity.
    - **Protection of underlying waterproofing systems:** from human activities (maintenance), root and animal penetration, and solar degradation.
    - **Waterproofing systems:** is the primary function of any modern roof. (Miller 2014).

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - The historic preservation aspects are related to the visibility of the green roof and the additional load that it may impose on the historic structure.
  - As previously discussed, the historic effect is too great to consider semi-intensive and intensive systems since they are designed to be viewed and create usable space.
  - The SHPO will have the final say in whether a green roof is an acceptable addition to a historic building. As discussed throughout the Guidelines, contact the SHPO early in the design process so that all parties are well-informed of the issues pertaining to a particular project.

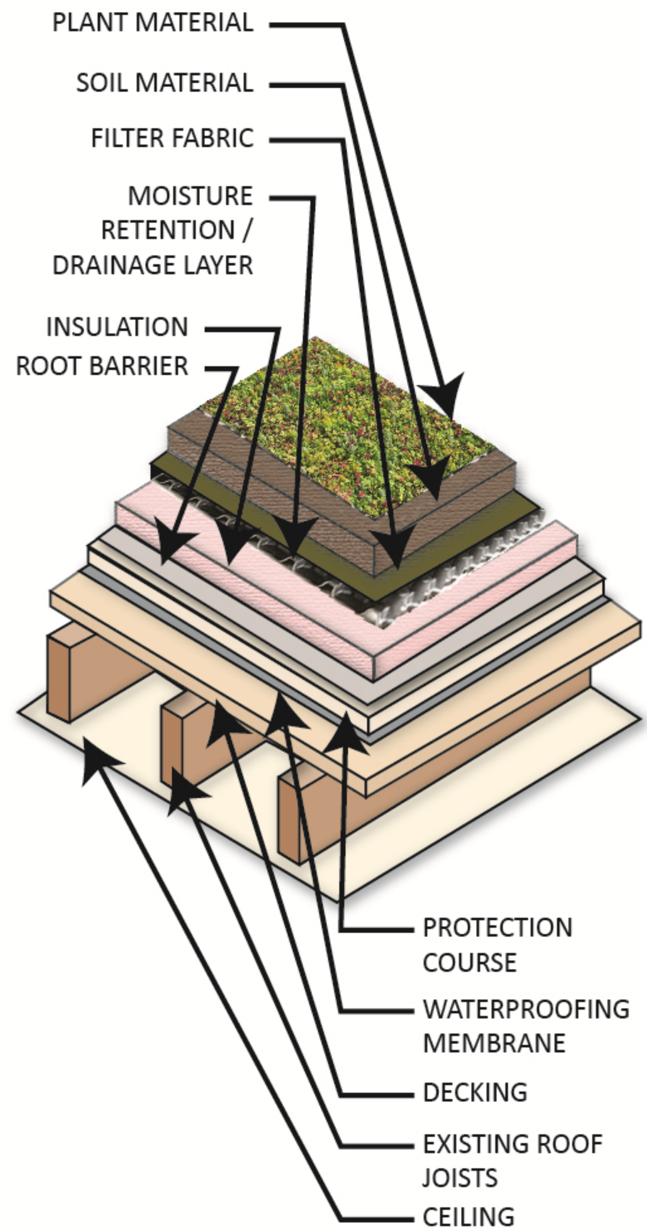


Figure 07 52-6 Extensive Green Roof System Diagram

CONSIDERATIONS FOR USING GREEN ROOFS ON HISTORIC BUILDINGS continued:

- **Energy Savings Potential:** As described above in General Notes, this Guideline does not attempt to calculate the energy savings on the features discussed. It does offer some general energy savings information for consideration.
  - The energy saving potential of a green roof lies in additional insulation that the plant material, soil, and drainage layers provide to the roof surface. In addition, the plant colors and reflectance qualities are more energy efficient than a dark, hard roof.
  - *Reduced energy use:* Green roofs absorb heat and act as insulators for buildings, reducing energy needed to provide cooling and heating. (U.S. Environmental Protection Agency, "Heat Island Effect: Green Roofs," 2013).

- **Cost Considerations:**
  - Estimated costs of installing a green roof start at $10 per square foot for simpler extensive roofing, and $25 per square foot for intensive roofs. Annual maintenance costs for either type of roof may range from $0.75–$1.50 per square foot. (Peck and Kuhn, "Design Guidelines for Green Roofs," 2003).
  - The initial costs of green roofs are higher than those of conventional materials.
  - Initial costs can be offset through reduced energy and storm water management costs, and by the longer lifespan of green roofs compared with conventional roofing materials. (U.S. Environmental Protection Agency, "Heat Island Effect: Green Roofs," 2013).
  - Detailed, full life-cycle analyses are trying to determine the net benefits of green roofs.
    - A University of Michigan study compared the costs of conventional roofs with the cost of a 21,000 sf (1,950 m^2) green roof and all its benefits, such as storm water management and improved public health from the absorption of nitrogen oxides.
      - In 2006, green roof = $464,000 to install versus $335,000 for a conventional roof. However, over its lifetime, the green roof would save about $200,000. Nearly 2/3 of these savings would come from reduced energy needs for the building with the green roof. (Talbot, Adriaens, and Clark 2008).

Figure 07 52-7 Green Roofs can be installed on pitched / sloped roofs.

Figure 07 52-8 Installation process on a sloped roof.

GUIDELINE DESCRIPTION: This Guideline will provide a general discussion of sealants (caulking) and focus on applications for blocking drafts and closing gaps for energy efficiency. It will discuss considerations when using a new joint sealant on a historic component. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, 04 21 Insulating Masonry Walls, and 06 81 Insulating Wood Structures, for appropriate strategies in preventing infiltration/exfiltration in walls.
- 07 21 Thermal Insulation, 07 31 Insulation for Sloped Roofs, and 07 51 Insulation for Flat Roofs, for information on eliminating air infiltration/exfiltration from the roof.
- 08 01 Increasing Energy Efficiency in Historic Windows, for window specific sealants.

GENERAL NOTES:

- There are five common caulk chemistry types:
  1. **Butyl** - solvent-based and characteristically stringy, which makes it difficult to apply in a finish-quality joint, but its adhesion and weather resistance make it applicable for sealing gutters, chimney flashings, walks, and other exterior joints.
  2. **Latex** - rubber-based and water-soluble, applied as a liquid. They are the least stretchy (7% to 10% elasticity). Work best on the interior where little movement is expected.
  3. **Acrylic** - a family of synthetic resins that are clear and water-soluble. Like latex caulks, they are easy to work with and paintable. Good for touch-ups and for filling small gaps.
  4. **Silicone** - formulated from silicone elastomers. It is virtually non-porous so it can make something watertight. It is most often used in plumbing applications (shower and sink installations) and some glasswork. Silicone is extremely rubbery (50% elasticity) but does not stick as well as other caulking and in its pure form, it cannot be painted.
  5. **Polyurethane** - based on the reaction of a glycol with an isocyanate, is solvent-based and is preferred for outdoor applications (exterior life span of 10-20 years). Bonds to most surfaces, including masonry and metal, hold up to heavy movement (25% elasticity), and can be painted. Also great for filling indoor gaps in floorboards because polyurethane can take the high-traffic stresses of floors. Due to their adhesive strength, removal usually involves cutting out or sanding off unwanted caulk.

Figure 07 92-1 1. Butyl Rubber Caulks

Figure 07 92-2 2. Butyl Tapes

Figure 07 92-3 3. Acrylic Latex Caulks and Sealants

Figure 07 92-4 4. Neutral Cure Silicone Sealants

Figure 07 92-5 5. Polyurethane Sealants

GENERAL NOTES continued:

- When specifying the appropriate sealants (caulking) in historic structures, consider location (interior or exterior), the goal to be achieved by sealing a joint (weatherproofing, blocking drafts, or closing gaps), and how much movement is expected. Factors to consider are:
  - Effectiveness and Durability: withstanding UV exposure, heating/cooling cycles, and flexibility when joining two components with different expansion/contraction rates.
  - Removable: Can it be removed without extreme measures?
  - Appearance**:** Does it attract dirt/dust?
- Sealants play an integral role in ensuring the effectiveness of insulation in any assembly by lowering the air exchange rate inside the envelope, thus in turn increasing the efficiency of the heating/cooling system.
- Caulking sealants are designed to prevent, **Vapor, Water, Gas/fumes and heated or cooled air** from travelling from one side of a building assembly to the other.
  - Any time a building is made more vapor-tight, there is a risk of trapping high moisture levels inside, which can lead to serious problems; from peeling paint to rotting wood. When caulking exteriors, remember that water primarily travels down, so caulking the undersides of window trim, door trim, or siding such as clapboards is recommended. This practice creates a path for some moisture migration out of the structure.

- **Locations to check and repair or replace Seals and Weatherstripping.**
  - No amount of insulation will help if air has a direct path to the exterior
  - Some common details to check for penetrations to prevent air infiltration are:
    - Fireplace dampers and chimneys
    - Weatherstripping on existing doors and windows
    - Exhaust fans
    - Electrical receptacles
    - Utility holes where they enter the building
    - Mortar joints
    - Joints between dissimilar materials
    - Tops of interior walls
    - Ductwork connections

SEALANT AND BACKER ROD DIAGRAM

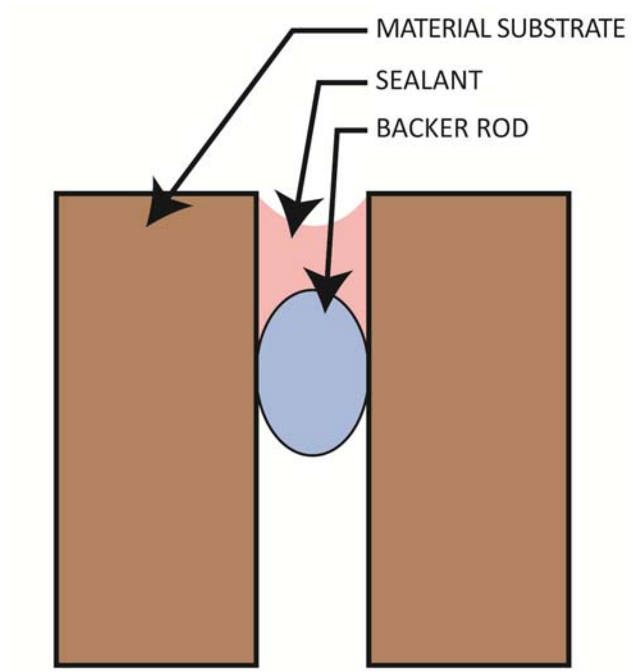


Figure 07 92-6

Never depend upon caulk alone to fill a gap any wider than ¼". If the joint is bigger, first insert backer rod (foam cording) in the gap, and then fill to the surface with the caulk.

Typical "hourglass" shaped joint showing material substrate on either side filled first with a non-adhering backer rod then with sealant that fills the joint cavity with a slightly recessed front. Note that the sealant adheres only to the substrate material.

CONSIDERATIONS FOR APPLYING SEALANT TO OPENINGS IN THE BUILDING ENVELOPE:

- **Approach:**
  - Conduct an infrared thermal imaging inspection to determine where the air infiltration/exfiltration occurs
  - Evaluate the materials that will be receiving the sealant
  - Evaluate the exposure of the sealant to UV, cold/heat cycles, likely movement
  - **Infiltration/Exfiltration:** Caulking is best applied to the envelope exterior, or the thermal boundary. Begin caulking at the periphery of the building's heated space: doors, windows, foundations, crawl spaces, attics, utility penetrations, and any other penetration from conditioned to unconditioned spaces (exhaust fans, lighting, IT data boxes, power lines, flues, gas lines, etc). In addition, seal all attic-to-building air leaks and seal around chimney and framing with a high-temperature caulk or furnace cement.
    - Duct exhaust fans to the outside. Seal the perimeter of the fan housing on attic side.
    - Seal around chimney and framing with a high-temperature caulk or furnace cement.
    - At the tops of interior walls, use long-life caulk to seal the smaller gaps and holes. Use expanding foam or strips of rigid foam board insulation for the larger gaps.

- **Applicable Secretary of the Interior Standards:**
  - 7: Gentle Treatment of Historic Materials
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - Any sealant that is used must be completely removable from the historic fabric.
  - The use of sealants is advised wherever a gap exists between two disparate materials.
  - **The design professional and owner** must remember the distinction between preventing conditioned air from escaping and preventing the envelope from breathing in the manner in which it was first built. (Refer to the discussion of this topic in *Walls and Foundations of Historic Buildings,n.d.,* 9-11*).*
  - **Maintaining the appearance:** The application of (caulking) sealants in historic projects must have no effect upon the historic appearance of the structure.
    - Visible sealant beads should be kept to a 3/8" maximum on a historic façade
    - Visible sealant beads should be selected for color match with an adjacent color

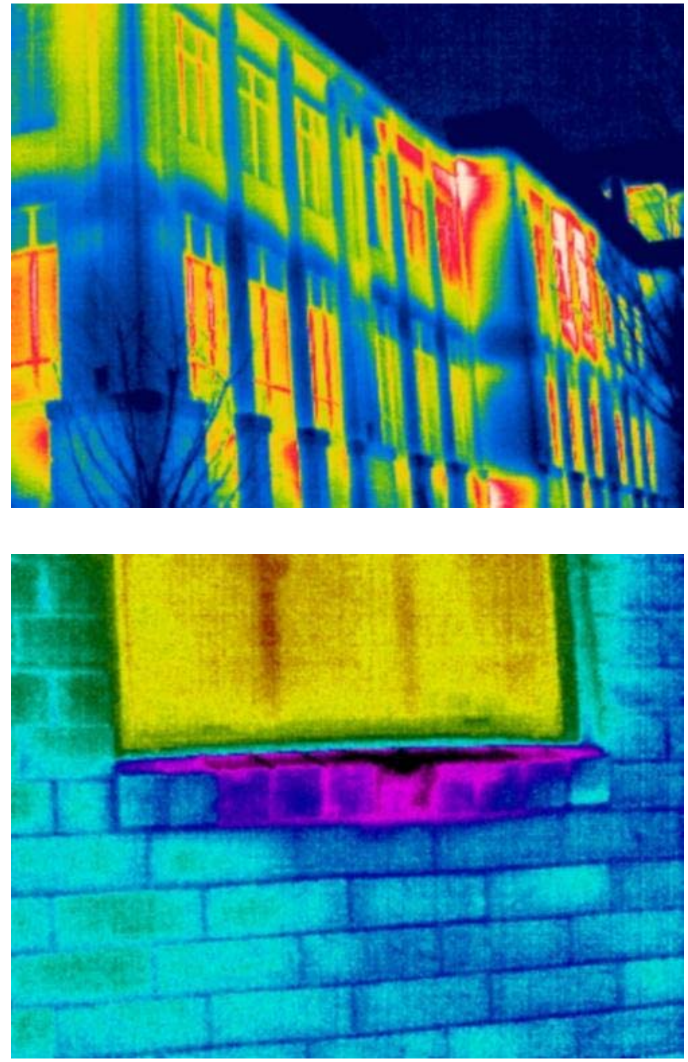


Figure 07 92-7
Installation voids, air leakage, structural defects, poor workmanship and moisture ingress are frequently located.

CONSIDERATIONS FOR APPLYING SEALANT TO OPENINGS IN THE BUILDING ENVELOPE continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - The Energy Efficiency Potential and Cost Considerations for this Guideline do not follow the same format as laid out in previous Guidelines and as discussed in the Introduction.
  - According to the U.S. Department of Energy, caulking drafty areas can cut energy costs 10%; and about 50% of the average fuel bill is the result of heat loss from air infiltration.
  - Sealants can help address the infiltration problem that allows cold air to enter a building at the lower elevations when heated air escapes at the higher points.
  - Depending on the severity of the problem, appropriately applied sealants can reduce conditioned air loss by a large factor. Calculating the loss is difficult, and each building will be different. The main idea is to allow conditioned air to remain in the heated envelope long enough to have a thermal effect on the interior fabric and contents.

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Most common sealant packaging is the ubiquitous "tube of caulk," which is 10.3 fluid ounces, usually priced in the $2.50 to $10.00 range. It can apply a quarter-inch bead approximately 31 feet in length. Such a gap can be thought of as an area (¼" x 31 feet = 93 square inches). (Interestingly, a smaller bead, 3/16" will fill a gap 55 feet in length. This area works out to be 123.75 square inches).
  - In terms of energy loss, this area can be responsible for the loss of a variable quantity of cubic feet of conditioned air per hour, depending on the pressure gradient present in the structure at any given time. Refer to the DAP website (http://www.dapspecline.com/products) for feet, inches, and mL.
  - Any gunned sealant (whether 10.3 fl. oz. or 40 fl. oz.) can effectively stop the flow of many cubic feet of conditioned air per hour. The cost of the sealant (and its application) must be weighed against the year-round loss of that energy for as many years as the sealant remains viable.

Sealant Classification by Performance (Movement Capacity)

Low Performance Sealants	Medium Performance Sealants	High Performance Sealants
	Hydrocarbon	Fluorosilicone

Low performance: +/- 0-5% movement capabilities, 10 year service life, and low cost.

Medium performance: +/- 5-12% movement capability, a 5-15 year service life, and medium cost.

High performance: greater than 12% movement capability, 10-50 years of service life, and relatively high cost.

Chart 07 92-1

GUIDELINE DESCRIPTION: Addresses the two principal causes of poor energy performance in historic windows, air infiltration and single glazing, and describes possible solutions to each. Unless noted otherwise, this Guideline applies to both historic wood and steel framed windows. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 00 01 Project Organization, Understand the current energy use of the historic structures
- 07 92 Joint Sealants, for information on sealing windows
- 08 52 Wood Windows – Backup Windows for additional Historic Preservation Effects

GENERAL NOTES:

- Developing a Plan: Developing a plan of modifications and repairs that will improve the performance and increase the useful life of the historic windows in the facility requires the completion of the following 3 steps:
  1. Assessment of Historic Significance of the windows
  2. Assessment of Physical Condition of the windows
  3. Determination of Repairs required, considering the following: Cultural resource concerns, Energy efficiency improvement measures, Cost / Benefit analysis

GENERAL HISTORIC PRESERVATION EFFECTS:

- Historic windows are almost always important character defining features. Therefore, their preservation requires special attention.
- Visual Appearance:
  - o Carefully consider all new and/or replacement products prior to installation in order to ensure that the appearance of the historic building remains unaltered.
  - o Any action taken to rehabilitate and/or increase energy efficiency in historic windows should, whenever possible, retain the historic colors, textures and profiles of window frames, muntins, mullions and glazing.
- Operability:
  - o Should be maintained unless the building's intended function dictates otherwise.
  - o Permanently closing a historically operable window could have adverse effects on the efficiency and operation of the existing HVAC system.

Components of Historic Windows

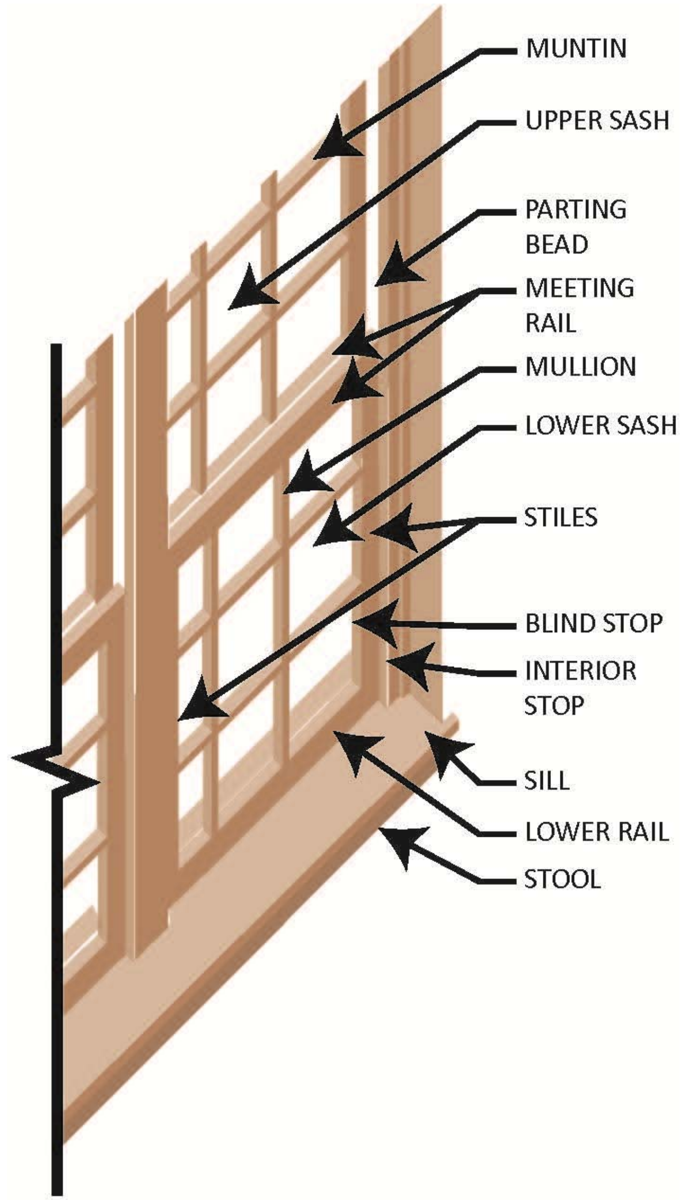


Figure 08 01-1

CONSIDERATIONS FOR AIR INFILTRATION:

- **Approach:**
  - Possible corrective actions to increase energy efficiency in historic windows in which air infiltration is a principle problem include, but are not limited to, the following:
    - Caulking or re-caulking around frames
    - Ensuring that glazing putty is sound, replace if it is not
    - Tightening loose fitting sashes / properly aligning all sections (in Steel Windows)
    - Replacing cracked or broken panes
    - Installing appropriate weatherstripping
    - Replacing ropes and broken pulleys
  - Health & Safety Risks:
    - Glazing putty often contains asbestos and should be tested before removal so that proper precautions may be taken. See Guideline 00 03, Hazardous Materials.
    - Use of acid compounds is an option when removing corrosion from steel window frames. These compounds can be dangerous, and must be treated with care.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 6: Repair of Deteriorated Historic Features
  - 7: Gentle Treatment of Historic Materials

- **Effects: See GENERAL HISTORIC PRESERVATION EFFECTS page 78**
  - Weatherstripping:
    - Some of the historically used products did not function well.
    - When installing weatherstripping, try to match the historic if possible. If not, use the most functional, best contemporary option with the least visual impact.
    - Sash locks installed on meeting rails help keep the sash tightly closed, increasing the effectiveness of the weatherstripping.
      - They "will usually be viewed as an acceptable contemporary modification in the interest of improved thermal performance." (Fisher, III 1986, 7).

Figure 08 01-2

Figure 08 01-3

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - If air infiltration is the cause of poor energy efficiency, it is difficult to precisely determine the amount of energy savings which may result when those areas of air infiltration are sealed. The savings will vary from case to case, depending on R-values of frame and glazing, R-values of the new sealant product and current amount of air infiltration.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Window Frame ______________
      - Window Glazing ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the window is exposed to outside temperatures.
    - That all windows are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Cost considerations vary from project to project, due to the physical condition and energy performance of the historic windows being considered.
  - "Windows provide views, daylighting, ventilation, and heat from the sun in the winter. Unfortunately, they can also account for 10%-25% of the heating bill by letting heat out." (U.S. Department of Energy; Energy Efficiency & Renewable Energy 2012)
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source -** ______________
    - **Cost -** ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, sealant and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR SINGLE GLAZING:

- **Approach:**
  - Possible corrective actions to increase energy efficiency in historic windows in which single glazing is a principle problem include, but are not limited to, the following:
    - Installing exterior or interior mounted storm windows
    - Retro-fitting insulating glazing into the existing frame
    - Installing aluminum frame storm panels on the interior of each light
    - Replacing entire historic unit with an in-kind replacement window
  - Health & Safety Risks: Paint from the era of historic windows often contains lead. Removal of lead containing paint can create toxic dust, and should be tested beforehand so that proper precautions may be taken.
    - Do not use heat to remove paint. This can damage the glass and release toxic fumes.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 6: Repair of Deteriorated Historic Features
  - 7:Gentle Treatment of Historic Materials

Examples of original Historic Single Pane Windows.

Figure 08 01-4

Figure 08 01-5

Figure 08 01-6

CONSIDERATIONS FOR SINGLE GLAZING continued:

- **Historic Preservation Effects: See GENERAL HISTORIC PRESERVATION EFFECTS page 78**
    - Storm Windows:
        - Exterior storm windows will likely have a greater adverse effect on the visual appearance of the historic window than interior storm windows.
        - Interior storm windows may cause condensation between the two windows, which could damage the historic window.
        - Proper installation of weatherstripping, caulking and weep holes reduces risk.
    - Insulating Glazing / Aluminum Frame Storm Panel:
        - Ensure that the existing frame can handle the additional weight of the insulated glass or aluminum frame storm panel.
        - If one of these options is pursued, the existing muntins / mullions must be wide enough to be retro-fitted without perceptibly changing the appearance of the frame. Maintain the historic profile of the muntins / mullions as much as possible.
        - If aluminum frame storm panels are used, provide proper venting in the sash stile.
    - If new aluminum frame storm panel is added, select a frame color carefully to be compatible with historic materials and colors.
    - In-Kind Replacements:
        - "Consider energy efficiency as one of the factors for replacements, but do not let it dominate the issue. Energy Conservation is not an excuse for the wholesale destruction of historic windows which can be made thermally efficient by historically and aesthetically acceptable means." (Myers 1981, 7).
        - In-kind replacement units will surely alter the character and appearance of the historic building, and should be used as a last resort.
            - In wood windows, even when there is evidence of much deterioration, an option exists of reinforcing the wood frame with steel rods and epoxy and/or Dutchman Repair of wood compartment.
        - When used, replicate the historic shapes of the muntins, mullions and sash, even if using a completely different frame material.
        - They are to be custom measured and manufactured for each opening, rather than using a standard window size and installing blocking in the opening for tight fit.

Examples of In Kind Replacement Windows

Figure 08 01-7
46 Blackstone, Harvard Campus, Cambridge, MA

Figure 08 01-8 **Figure 08 01-9**
Cambridge City Hall Annex, Cambridge, MA

CONSIDERATION FOR SINGLE GLAZING continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - If single glazing is the cause of poor energy efficiency, it can be assumed that the solution will involve adding insulation to the glazing in some way. While the savings will always vary from case to case, depending of the R-values of the existing window and those of the proposed addition or replacement or back-up products, there is slightly more information available which can be used to approximate this number.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Window Frame ______________
      - Window Glazing ______________
      - Sealant ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the window is exposed to outside temperatures (not basement).
    - That all windows are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Cost considerations vary from project to project, due to the physical condition and energy performance of the historic windows being considered.
  - "Windows provide views, daylighting, ventilation, and heat from the sun in the winter. Unfortunately, they can also account for 10%-25% of the heating bill by letting heat out." (U.S. Department of Energy; Energy Efficiency & Renewable Energy 2012).
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, sealant and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This Guideline will look at different ways of bringing natural light into a building. It will first consider the original fenestration design intent and then supplement with other natural lighting strategies. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 31 Insulation for Sloped Roofs and 07 51 Insulation for Flat Roofs, for Roof information
- 08 01 Increasing Energy Efficiency in Historic Windows and 08 52 Wood Storm Windows, for additional information on Window renovations
- 26 51 High Efficiency Lighting. Electric lighting systems can be programmed to work in conjunction with Natural Lighting to maximize efficiency.

GENERAL NOTES:

- Does the original configuration of the building provide adequate illumination for the purposes the building is intended to serve? If so, the strategy should be to maximize the original fenestration.
- If additional lumens are required, the strategy of installing skylights can be investigated. The costs associated with adding these features can then be compared to the annual costs of installing and operating artificial lighting.
- Consider creating (or re-creating) transoms and clerestory windows in interior walls to allow daylight to penetrate further into the interior of a building.

Figure 08 02-1
Before: The original windows are partially covered by a new lay-in new ceiling.

Figure 08 02-2
After: Original windows opened to full height, admitting twice the light as in the “office” configuration.

CONSIDERATIONS FOR RE-OPENING FULL-HEIGHT WINDOWS:

In instances where a ceiling has been lowered in a previous remodel and the original windows have been partially obscured, the windows should be fully re-opened to their original size and the ceiling should be restored, or the ceiling can be reconfigured with a furr-down at an angle to provide a "skirt" or reflector to bounce more daylight into the interior space.

- **Approach:**
  - Determine the amount of lumens (lighting) necessary for the proposed use.
  - Determine the amount of repair necessary to restore the original windows to use; a spreadsheet can assist in cost estimation and help the contractor in preparing a bid.
  - Determine the R-value of the existing windows, and if storm/ back-up units are viable.
  - Determine whether utility upgrades are needed.
  - What are the heating/cooling consequences of restoring full-height ceilings?

- **Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 6: Repair of Deteriorated Historic Features
  - 10: Recognizing New Additions

- **Historic Preservation Effects:**
  - Restoring full-height windows has virtually no ill effect on the exterior character.
  - Carefully evaluate interior features to determine that a new dropped plenum does not conflict with the SOI Standards.

Figure 08 02-3

Before: This image shows the exterior impact of the lowered ceilings, complete with lightweight white foam boards installed above the acoustic lay-in ceilings to mimic drawn shades.

Figure 08 02-4

After: The exterior following restoration of the full-height windows.

CONSIDERATION FOR RE-OPENING FULL HEIGHT WINDOWS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - The cost/benefit analysis of this Approach requires comparing the costs of installing and operating artificial lighting (with assumed future energy costs) against the more easily-determined one-time expense of re-configuring the full-height windows and ceilings.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Window Frame ______________
      - Window Glazing ______________
      - Sealant ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the window is exposed to outside temperatures (not basement).
    - That all windows are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Associated expenses include:
    - Restoration of the entire window unit**.**
    - Removal and disposal of dropped ceiling (if present).
    - Restoration of the historic ceiling.
  - Back-up or interior storm windows costs.
  - Installation of dimming/daylight lighting controls.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, and other materials* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS FOR INSTALLING SKYLIGHTS:

- **Approach:**
  - Determine a location on the roof that is not visible on the significant façades of the structure. This may include a side view, or all views.
  - Examine the ceiling in the interior space to be illuminated. Is it historically significant?
  - Was an existing skylight or roof lantern removed or covered up because of potential leaks? Perhaps it can be restored using photographs as a guide.
  - Examine the existing roof structure.
    - Can it support the additional weight of the proposed skylight?
    - Will the addition of a skylight adversely affect the roof drainage? How can that be addressed?
    - Will the addition of a skylight interfere with any necessary foot paths that exist or may be added on the roof for mechanical equipment maintenance?
  - Additional Information
    - Energy Star® products. Refer to DOE guidelines under section 103 of the Energy Policy Act or 2005 (Energy Policy Act of 2005, Sec. 104)
    - Enhance Indoor Environmental Quality. *Daylighting*. Achieve a minimum daylight factor of 2 percent (excluding all direct sunlight penetration) in 75 percent of all spaces occupied for critical visual tasks. Provide automatic dimming controls or accessible manual lighting controls, and appropriate glare control. (ACHP, et al 2011, 5) and (Federal Leadership in High Performance and Sustainable Buildings n.d., 4).

- **Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
  - 10: Recognizing New Additions

- **Historic Preservation Effects:**
  - If the SOI Standards cannot be met, then another lighting strategy may be necessary, depending on the proposed use of the building.

Gerding Theater, Portland Armory, Portland, OR

Figure 08 02-5
The structure was deemed historic, but not the roof. Skylights were strategically placed around the structure.

Figure 08 02-6
Full view of upper level with the skylights and structure.

CONSIDERATION FOR INSTALLING SKYLIGHTS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - This topic can be dealt with in almost the same way as the full-height window issue. The cost of a skylight is generally a one-time expense. Installation of artificial light involves purchase and installation costs, operation expense, and replacement costs.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Window Frame ______________
      - Window Glazing ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the window is exposed to outside temperatures (not basement).
    - That all windows are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Demolition of ceiling and roof.
  - Purchase and installation price.
  - Restoration of ceiling and roof, or skylight.
  - Insulation of the skylight walls in a "cold roof" situation.
  - Selection of glazing type (Low Emissivity; Low "E") can boost energy.
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, and other materials* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: This Guideline will discuss adding vestibules either to the exterior of the building or to the interior. It will also cross reference with other applicable divisions. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 21 Thermal Insulation, for general insulation information
- 07 92 Joint Sealants, for general sealant information
- 08 01 Energy Efficiency in Historic Windows, for weatherstripping information

CONSIDERATIONS:

- **Approach:**
  - Very closely discuss with CRM/SHPO
  - Create a secondary air space or "air lock"
    - Effectively, it reduces air infiltration when the exterior door is open.
  - Retain if already existing: Exterior and interior vestibules are common architectural features of many historic buildings and should be retained wherever they exist. (Hensley and Aguilar n.d., 10).
  - Before:
    - Energy Audit – how much energy is really being lost through the door?
      - Will other energy saving retrofits be more beneficial?
    - Other options – Can weatherstripping achieve significant energy savings?
  - Adding:
    - Can be appropriate to add "For example, new glazed interior vestibules may be compatible changes to historic commercial and industrial buildings." (Hensley and Aguilar n.d., 10).
    - "…usually result in too great a change to the character of primary entrances, but may be acceptable in very limited instances, such as at rear entrances. [They] should be compatible with…the historic building." (Hensley and Aguilar n.d., 10).
    - Determine location based on energy savings and cultural resource impact
    - Can also help meet UFC requirements for glass resistance.

Figure 08 41-1
Interior of Botts Hall after construction of vestibule is complete. Notice stylistic similarities between these new doors and the original doors.

Figure 08 41-2
Exterior of Botts Hall after construction of vestibule is complete. The only change to the exterior was to repair the original doors.

CONSIDERATIONS continued:

- **Approach continued:**
  - Example: Botts Memorial Hall in Special Collections Library, Albuquerque, New Mexico
    - Background
      - Built in 1925, with Botts Hall (a public meeting room) added in the 1950's
      - It is on the National Register of Historic Places and is an Albuquerque Landmark
      - It was "modernized" in the 1970's; the original doors were retained.
    - Issue
      - Air and noise leaked through the major entry door into Botts Hall
    - Solution
      - A new vestibule was added to control the outside noise and reduce the loss of conditioned air.
      - The vestibule design allows for removal without damage to original space, and respects the original building design.
      - Retains the original front doors; provides inner doors that imitate the original door panels with glass; repeats the transom design
      - Deep enough to allow for wheelchair passage with one set of doors closed.

- **Applicable Secretary of the Interior Standards:**
  - 1: Use for intended historic purpose
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
  - 10: Recognizing New Additions

- **Historic Preservation Effects:**
  - Addition of a vestibule must follow a respectful design; should be removable, and should clearly be a contemporary addition.
  - The addition of a vestibule, whether interior or exterior, is one of the greatest potential energy savings measures discussed in this report. Careful analysis is critical to avoid/minimize detrimental impacts.

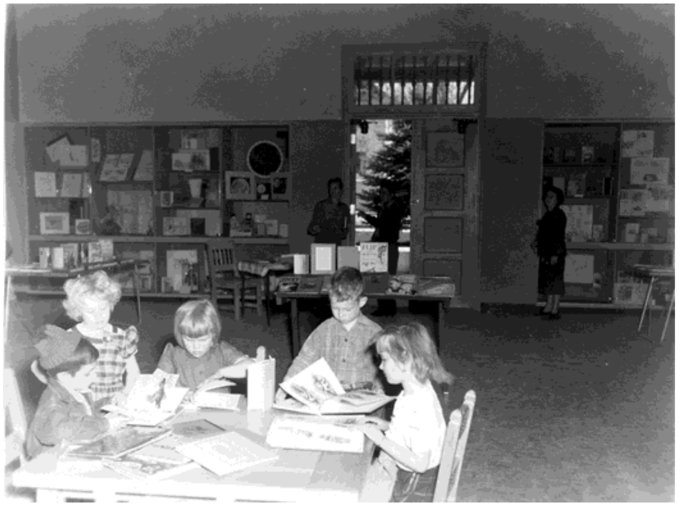


Figure 08 41-3
Historic photograph of Botts Hall in the 1950's

Figure 08 41-4
Same space as the above photograph, this photo was taken prior to construction of the vestibule. Notice the light (and air) seeping in around the now blocked transom.

CONSIDERATION continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Door/Entrance Frame ______________
      - Door/Entrance ______________
      - Sealant ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the doors/entrances are exposed to outside temperatures.
    - That all doors/entrances are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, sealant and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

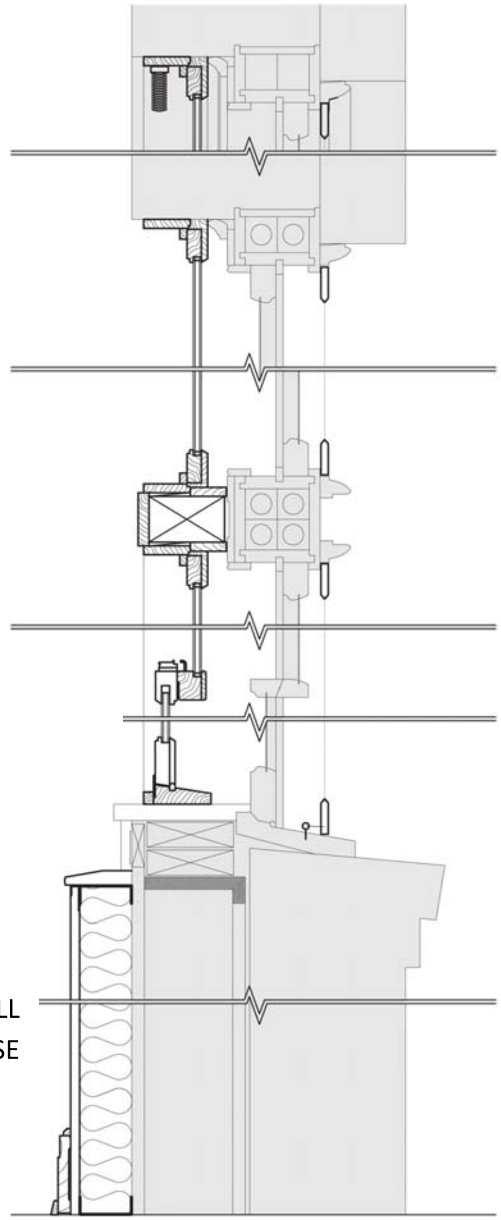
chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: The addition of a new interior double paned window is a solution to provide additional thermal comfort and reduce heat transmission when the frame profile of the historic window does not allow for the addition of a second pane of glass. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

Construction drawing showing the addition of a Wood Back Up Window to a Historic Window

Figure 08 52-1



RELATED GUIDELINES:

- 07 92 Joint Sealants, for general sealant information
- 08 01 Increasing Energy Efficiency in Historic Windows, for general window information
- 23 08 Selecting HVAC Systems

CONSIDERATIONS:

- **Approach:**
  - **Qualitative aspects**:
    - The thermal comfort of occupants
    - Minimizing air infiltration in old windows
  - **Wall thickness**: It must be thick enough to contain the new back-up window behind the historic window without detracting from historic, interior features. The illustration above was installed in a double width, un-reinforced, brick, masonry wall.
  - **Cleaning:** Allow for cleaning both windows.
    - IE: if the historic window is a single hung window, the new back-up window could be a double hung allowing for cleaning both sashes of the historic window from the inside. Many wood windows today snap out of the frame which allows for cleaning.
  - **Operability:** Should be kept or restored whenever possible. Coordinate with the HVAC system to provide natural ventilation when feasible.
  - **Window Swing:** If the historic windows swing out, the new windows could swing in. If the historic windows swing in, the back-up windows may have to take a different configuration, or back-up windows may not be a suitable solution.
  - Recommended: identify, retain and preserve windows important in defining the historic character of the building. Important features include frames, glazing, sills, heads, hoodmolds, jambs, shutters and blinds, as well as others. For more information see: http://www.nps.gov/history/hps/tps/standguide/preserve/preserve_windows.htm

CONSIDERATIONS continued:

- **Applicable Secretary of the Interior Standards**:
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - **Profile:** Back up windows should retain the profile of the historic windows.
    - IE: sash frame and meeting rails thickness should be the same or less than the original frame members
  - **Frame Finish:** A darker shade of finish on the frame will show through to the outside less than a lighter shade of finish.
  - **Pane Dividers:** Back-up windows may have fewer pane dividers than the exterior, historic windows with CRM/SHPO review and comment. If there are fewer pane dividers, the "double image" produced by the back-up windows will be reduced.
  - **Glass Color:** The glass in the back-up window should not change the apparent color of the historic glazing.
  - **Force Protection / Anti-Terrorism:** The UFC contains clear requirements regarding windows if the building is located within the Explosives Safety Quantity Distance (ESQD). Many of the UFC requirements conflict with the Secretary of the Interior Standards for Historic Preservation, but will still take precedence over the Secretary of the Interior Standards. Careful planning by the Design Team is needed to ensure that if this situation arises, the best option is chosen to try and meet both the UFC and SOI Standards. See the following page for an example of a possible solution.

Figure 08 52-2
Installed Back up Windows

Figure 08 52-3
Close-up of installed interior back-up window

CONSIDERATIONS continued:

- **Historic Preservation Effects continued:**
  - **Force Protection / Anti-Terrorism continued:**
    - Ideally, in a historic building, force protection and anti-terrorism measures would be handled in the site, rather than at the building.
    - The action suggested in this Guideline – installing a back-up window – would be a good solution to use in a historic building located outside of the UFC defined Explosives Safety Quantity Distance (ESQD).
    - Removable Blast Guard – If force protection and anti-terrorism need to be handled at the building.
      - Meets the functional requirements in the UFC.
      - Leaves the historic window intact.
      - New construction is visibly new, but still emulates the historic window configuration.

Removable Blast Guard

Figure 08 52-4
Possible solution for Force Protection and Anti-Terrorism at a historic building. Build a removable blast guard at the interior of the space, taking care to mimic the configuration of the existing windows.

CONSIDERATIONS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Can be evaluated using a simple formula:

    Rh (historic window) + Ra (air space) + Rb (back up window)
    = x/Rh = Increase in insulative value of window system

    - IE: Most historic windows are single paned. The back up is double-paned, and specified to have a minimum R-factor of 2.85. There is a one inch air space between the windows.
    - The R-Factor for a single pane of glass is 0.9. Rh = 0.9
    - Ra = 1.0
    - Rb = 2.85
    - The installation of the back up window increases the insulative value of the system by a factor of 0.9 + 1 + 2.85 = 4.75/0.9 = 5.28.
  - **Emissivity**: Using low emissivity glass can also contribute to energy savings.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Existing Window Frame ______________
      - Existing Glazing ______________
      - New Window Frame ______________
      - New Glazing ______________
      - Sealant ______________
      - Existing Air Infiltration ______________
  - **Assumptions** (both for the calculator and table)
    - That the windows are exposed to outside temperatures.
    - That all windows are the same regardless of orientation.

Sources:
R-Values

- *Window Frame/Glazing, sealant and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

CONSIDERATIONS continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
    - There is a wide variety of quality levels of wood windows that will affect the cost. Costs vary with the quantity of windows to be purchased and installed, whether the sizes are standard or special, proximity to manufacturer, and local market factors.
    - Depending on the Code Officials interpretation, the historic windows may not need to meet the local wind resistance factors if the historic windows have withstood local winds for many years.
    - **Before using the online calculator or provided table, determine the following:**
        - **Heat Source** - ______________
        - **Cost** - ______________
        - **Location -** ______________
        - **Total Heating Degree Days (HDD)-** ______________
        - **Total Cooling Degree Days (CDD) -** ______________

GUIDELINE DESCRIPTION: This Guideline will discuss how window treatments or films can be an effective method for improving the interior environment and thermal performance of a historic building when other methods are not feasible. Use this Guideline with 08 01 Increasing Energy Efficiency in Historic Windows. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 03 31 Insulating Concrete Walls, review for information on insulation.
- 04 21 Insulating Masonry Walls, review for information on insulation.
- 06 81 Insulating Wood Structures, review for information on insulation.
- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 08 01 Increasing Energy Efficiency in Historic Windows
- 08 41 Reducing Air Transfer at Historic Doors/Entrances

GENERAL NOTES:

- Follow the "Developing a Plan" under General Notes in Guideline 08 01 to determine if a window treatment or film is the proper avenue for increasing thermal performance of the window.
- Historic windows are almost always important character defining features. Therefore, their preservation requires special attention.
- Visual Appearance:
  - Carefully consider all new and/or replacement products prior to installation in order to ensure that the appearance of the historic building remains unaltered.
  - Any action taken to rehabilitate and/or increase energy efficiency in historic windows should, whenever possible, retain the historic colors, textures and profiles of window frames, muntins, mullions and glazing.
- Reducing heat loss in winter and heat gain in summer are the primary reasons to consider the use of a window treatment or film, but should only be considered AFTER the windows have been inspected to ensure that they are in proper working order.
- Window treatments are not effective at reducing air infiltration.
- While not discussed here, research whether the building had awnings at a significant point and if the reintroduction is viable. Awnings are very effective in reducing summer heat gain.

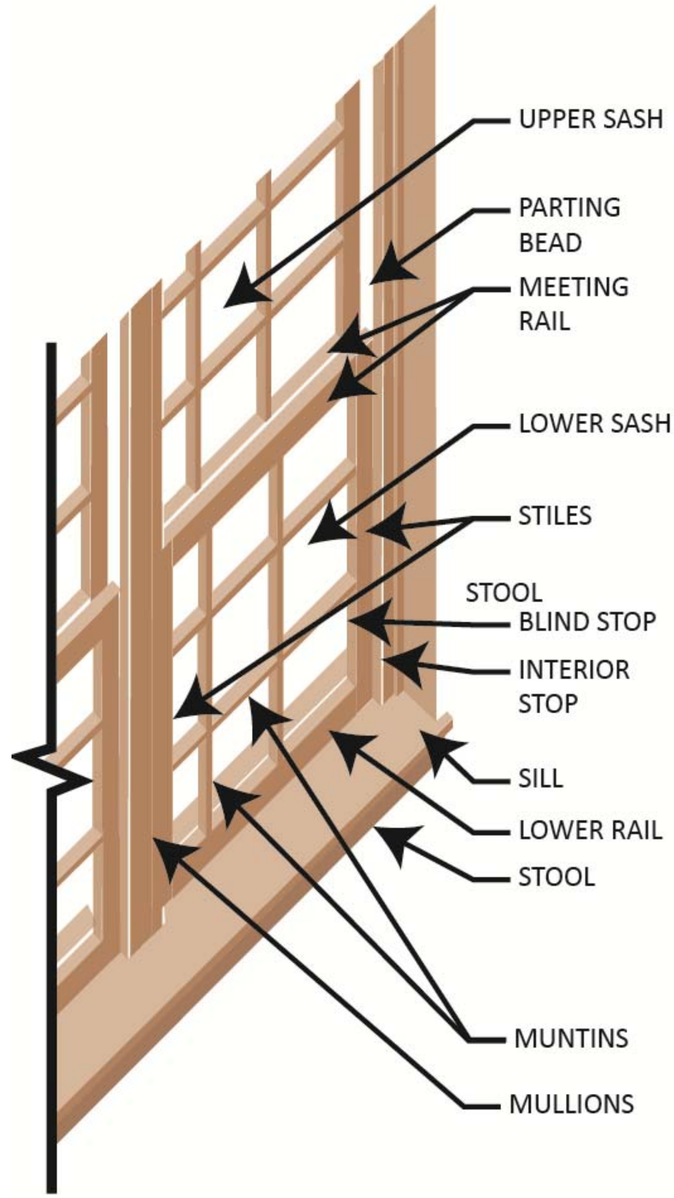


Figure 12 22-1 Ensure that any added window treatment does not damage or even change the historic look of the historic window.

CONSIDERATIONS FOR ADDING WINDOW BLINDS:

- **Approach:**
  - Window blinds—vertical or horizontal slat-type—are more effective at reducing summer heat gain than winter heat loss.
  - Interior Blinds
    - Because of the numerous openings between the slats, it is difficult to control heat loss through interior window blinds.
    - Slats offer flexibility in the summer. Unlike shades, slats can be adjusted to control light and ventilation.
      - For example, when completely closed and lowered on a sunny window, highly reflective blinds can reduce heat gain by around 45%.
      - They can also be adjusted to block and reflect direct sunlight onto a light-colored ceiling. A light-colored ceiling will diffuse the light without much heat or glare.
  - Exterior Blinds
    - Exterior roller blinds are usually made of wood, steel, aluminum, or vinyl.
    - They are mounted above the window, and side channels guide them as they are lowered and raised.
    - Because of how exterior blinds are installed and how they can change the visual appearance of a building, they are not recommended for use on a historic structure.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - It is important to work with the CRM, Design Team and the local SHPO to ensure that the blind installed will not adversely affect the building.
  - Unless installation causes irreparable damage to the historic window, blinds are a feasible and economic method to improve the thermal performance of the building.

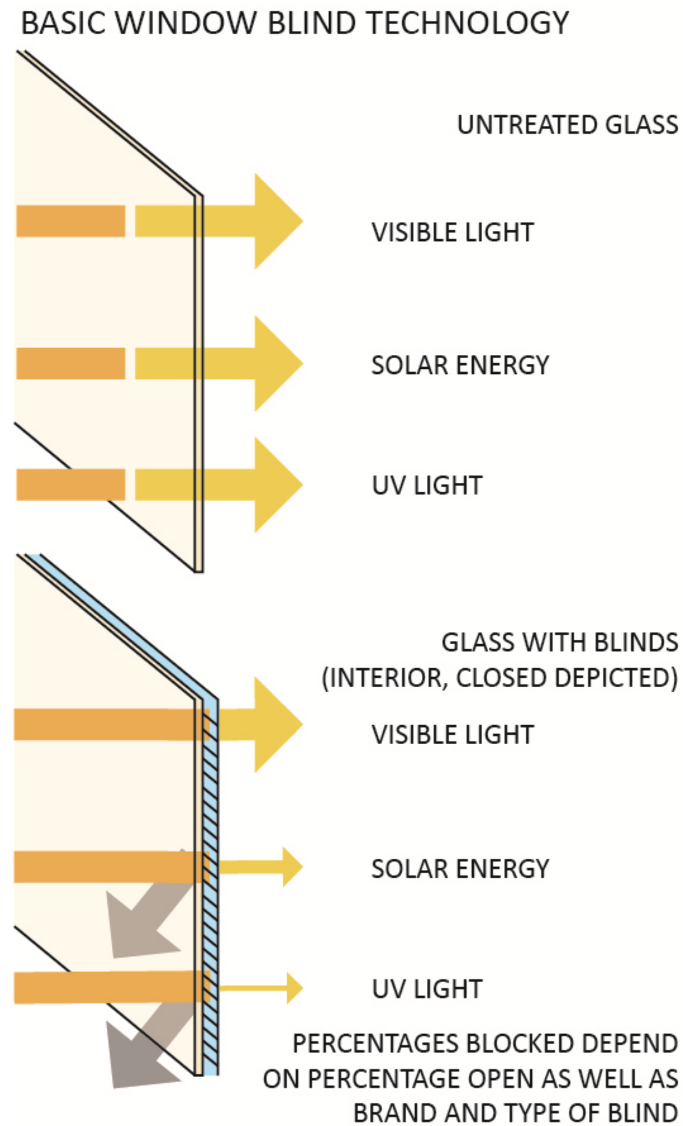


Figure 12 22-2

CONSIDERATIONS FOR ADDING WINDOW BLINDS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - **Part of a system:** Window blinds are part of the larger building envelope system. They cannot be analyzed for their specific energy savings potential. For a more general discussion on determining the energy savings potential of the entire exterior building envelope, see Guidelines 03 31 Insulating Concrete Walls and 04 21 Insulating Masonry Walls.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Window blinds are an economical choice for any construction project, especially ones on a historic building where the actual structure and features will not be changed.
  - Also important is that blinds can be added after other renovation is complete and can be easily changed years later.
  - (Energy.gov, "Energy-Efficient Window Treatments," 2012)

Figure 12 22-3 Interior Window Blinds

Figure 12 22-4 Exterior Window Blinds

CONSIDERATIONS FOR DRAPES:

- **Approach:**
  - A drapery's ability to reduce heat loss and gain depends on several factors: fabric type (closed or open weave) and color.
    - With such a wide variety of draperies available, it is difficult to generalize about energy performance.
  - During summer days, close draperies on windows receiving direct sunlight to prevent heat gain.
    - Studies demonstrate that medium-colored draperies with white-plastic backings can reduce heat gains by 33%.
    - Draperies also stay cooler in the summer than some other window treatments because their pleats and folds lose heat through convection.
  - When drawn during cold weather, most conventional draperies can reduce heat loss from a warm room up to 10%. Therefore, in winter, close all draperies at night, as well as draperies that do not receive sunlight during the day.
  - To reduce heat exchange or convection, draperies should be hung as close to windows as possible.
  - Also let them fall onto a window sill or floor.
  - For maximum effectiveness, install a cornice at the top of a drapery or place the drapery against the ceiling. Then seal the drapery at both sides and overlap it in the center. Then use Velcro or magnetic tape to attach drapes to the wall at the sides and bottom.
    - If done properly, heat loss may be reduced by up to 25%.
  - Two draperies hung together will create a tighter air space than just one drapery. One advantage is that the room-side drapery will maintain approximately the same temperature as the interior space, adding to a room's comfort.

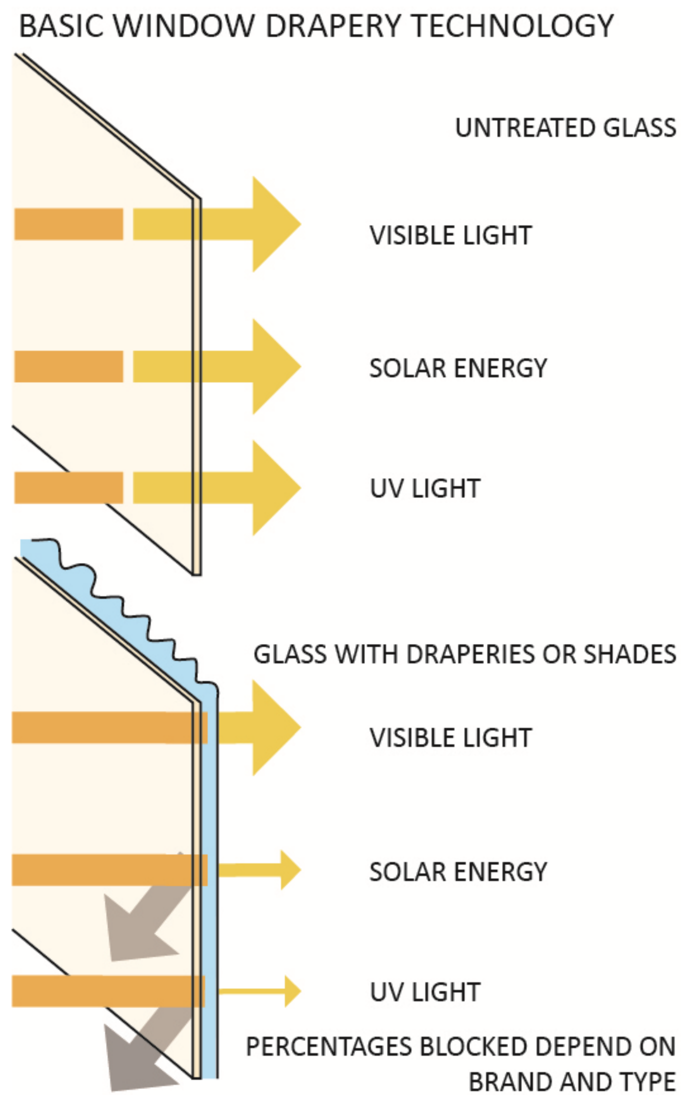


Figure 12 22-5

CONSIDERATIONS FOR ADDING DRAPES continued:

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - It is important to work with the CRM, Design Team and the local SHPO to ensure that the drapes installed will not adversely affect the building.
  - Unless installation causes irreparable damage to the historic window or wall, drapes are a feasible and economic method to improve the thermal performance of the building.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - **Part of a system:** Window drapes are typically considered an aesthetic aspect of the interior design of the building and are not necessarily a contributing component in the thermal performance of the building envelope system. They cannot be analyzed for their specific energy savings potential. For a more general discussion on determining the energy savings potential of the entire exterior building envelope, see Guidelines 03 31 Insulating Concrete Walls and 04 21 Insulating Masonry Walls.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Window drapes are more of an aesthetic choice than an energy performance choice. However, if approached conscientiously, energy performance goals can be met for little or no additional cost over the aesthetic choice.
  - Another important consideration is that blinds can be added after other renovations are complete and can be easily changed years later.
  - (Energy.gov, “Energy-Efficient Window Treatments,” 2012)

Figure 12 22-6

Figure 12 22-7

CONSIDERATIONS FOR FILMS:

- **Approach:**
  - Highly-reflective window films help block summer heat gain. They are best used in climates with long cooling seasons, because they also block the sun's heat in the winter.
  - The effectiveness of these reflective films depends on:
    - Size of window glazing area.
    - Window orientation.
    - Climate.
    - Building orientation.
    - Whether the window has interior insulation.
  - Silver, mirror-like films typically are more effective than the colored, more transparent ones.
  - East- and west-facing windows, because of their greater potential for heat gain, can benefit more from these films.
  - North-facing windows will not benefit from them, and south-facing windows may benefit somewhat, but the benefit could be offset by the reduction of heat from the winter sun.
  - These films have some overall disadvantages:
    - Loss of interior light or visible transmittance.
    - Impaired outside visibility.
    - Extra care required for cleaning.
    - Reflections.
  - Films can be applied without a contractor over existing windows.

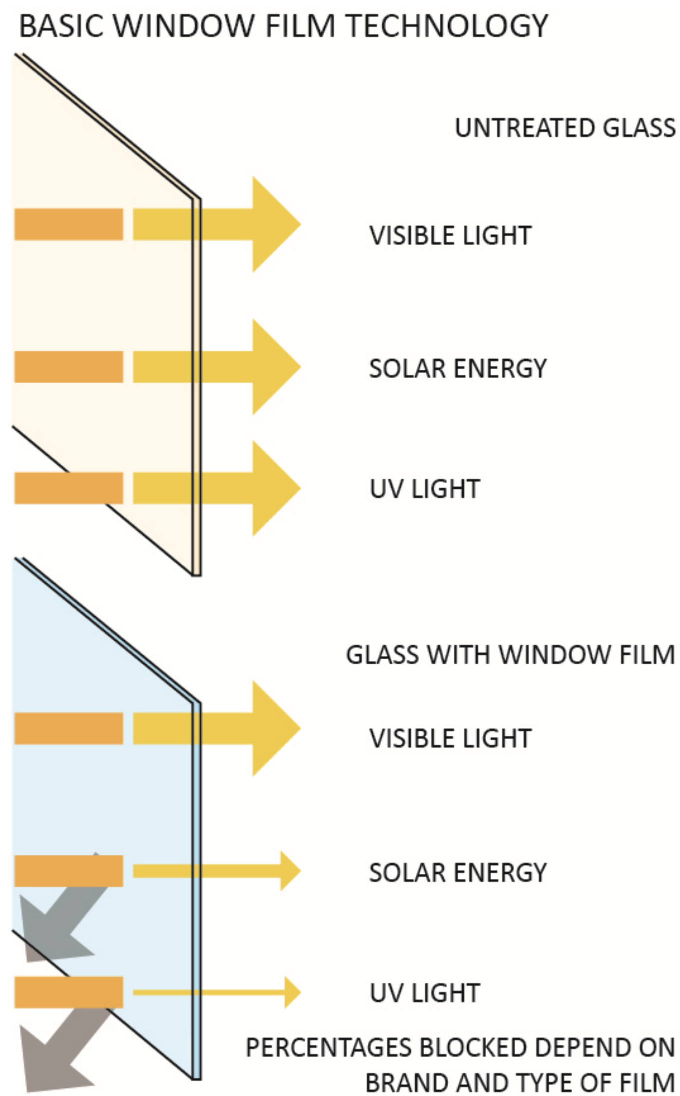


Figure 12 22-8

CONSIDERATIONS FOR ADDING FILMS continued:

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - It is important to work with the CRM, Design Team and the local SHPO to ensure that the films installed will not adversely affect the building.
  - Unless installation causes irreparable damage to the historic window, films are a feasible and economic method to improve the thermal performance of the building. The SHPO might comment that the films should be removable.

Figure 12 22-9

Figure 12 22-10 3M Solar and Security window films, especially designed for government projects.

CONSIDERATIONS FOR ADDING FILMS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts as well as a step by step example of how a calculation can be done**.**
  - Certain manufacturers provide an energy savings analysis as part of their service.
  - If single glazing is the cause of poor energy efficiency, it can be assumed that the solution (a window film) will change the performance of the glazing in some way. While the savings will always vary from case to case, depending of the R-values of the existing window and those of the proposed film, there is slightly more information available which can be used to approximate this number.
  - **Before using the online calculator or provided table, determine the following:**
    - **R-Values** for window materials**:**
      - Window Frame ______________
      - Window Glazing ______________
      - Sealant ______________
      - Existing Air Infiltration ______________
  - **Assumptions:** (both for the calculator and table)
    - That the window is exposed to outside temperatures (not basement).
    - That all windows are the same regardless of orientation.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Window films can be more expensive than the other window treatments discussed in this chapter. However, they are still an economic choice with a low impact.
  - "Windows provide views, daylighting, ventilation, and heat from the sun in the winter. Unfortunately, they can also account for 10%-25% of the heating bill by letting heat out." (U.S. Department of Energy; Energy Efficiency & Renewable Energy 2012).
  - **Before using the online calculator or provided table, determine the following:**
    - **Heat Source** - ______________
    - **Cost** - ______________
    - **Location -** ______________
    - **Total Heating Degree Days (HDD)-** ______________
    - **Total Cooling Degree Days (CDD) -** ______________

Sources:

R-Values

- *Window Frame/Glazing, sealant and other materials -* www.coloradoenergy.org/procorner/stuff/r-values.htm

Cost of Heat

- energy-models.com/tools/average-electric-and-gas-cost-state

HDD and CDD

- www.degreedays.net/

Energy-Efficient Window Treatments

- http://energy.gov/energysaver/articles/energy-efficient-window-treatments

Online Calculator

chuck-wright.com/calculators/insulpb.html

This calculator takes into account efficiencies of heating and cooling equipment just like the excel table in Part 1, Introduction, Item 3, also found in Appendix F.

GUIDELINE DESCRIPTION: Fire protection systems, usually fire sprinkler systems, are installed because of code requirements. The following Guideline will help determine the proper fire suppression system for the historic application in question. Historic Preservation projects call for the consideration of the issues of preserving historical appearance, and may, therefore, involve alternate approaches to fire safety and sensitivity in the installation of fire suppression systems. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 06 82 Reusing Historic Wood Structures
- As this Guideline relates to code requirements and safety concerns, all Guidelines are related to some extent.

GENERAL NOTES:

- The primary intent is to ensure the protection of the qualities and characteristics of a historic property (individual or district) that make it significant.
- The 3 major challenges of fire suppression retrofitting in historic buildings are:
  - To provide the protection of life.
  - To protect the property.
  - To ensure that the installation of fire safety devices has minimal impact on the historic features of the property.
- There are several different types of automatic fire suppression systems that will be discussed below:
  - **Dry Pipe System**
  - **Wet Pipe System**
  - **Deluge System**
  - **Pre-Action System**
  - **Chemical Based System**

System type based on location		
Sprinkler Installation Type		**Installed Where**
1	Wet Pipe System	Occupancies with temp 95*C > X > 0*C
2	Dry Pipe System	Occupancies with risk of temp X < 0*C and X > 95*C
3	Deluge System	Occupancies with rapid fire spread
4	Pre-Action Pipe System	In occupancies where water damage is not accepted by accidental activation

Chart 22 11-1

Cost Comparison of the different types of systems		
Sprinkler Installation Type	**New Construction Cost**	**Retrofitting Cost**
Dry Pipe System	$3-$5/sf	$10-$12/sf
Wet Pipe System	$2-$3/sf	$10-$12/sf
Deluge System	$1-$2/sf	$10-$12/sf
Pre-Action Pipe System	$1-$2/sf	$10-$12/sf

Chart 22 11-2

GENERAL NOTES continued:

- Regardless of the specific type of system chosen, there are several different pieces of equipment that each contain:
  - Fire alarms
    - Fire Alarm Systems (FAS) are required for all state buildings unless a variance is approved by the State Fire Marshal's Office.
    - Comprised of a main control panel that has smoke detectors, heat detectors, manual pull stations, and special suppression systems that alert the panel to activate in case of alarm.
    - Locate where routing of conduit will not permanently alter the historic fabric.
    - Select based on appearance so that the alarm style is in harmony with the other architectural elements of the historic building.
  - Fire extinguishers (portable and cabinets)
    - Portable fire extinguishers are the first line of defense for fires of a limited size.
      - They are needed even if the property is equipped with an automatic suppression system, standpipe and hose, or other fixed protection equipment.
    - Surface mounted or in recessed cabinets.
      - Surface mounted are more visible from all angles of the space, but do not permanently alter the wall.
      - Recessed cabinets can permanently alter historic walls, but are less obtrusive.
  - Fire proofing materials are required to augment existing nonconforming historic construction.

GENERAL HISTORIC PRESERVATION EFFECTS:

- Install fire proofing materials so that the significant aspects are not permanently altered.
- Use surface mounted fire extinguisher cabinets in areas where recessed cabinets would alter the significant historic fabric, such as marble wainscoting.
- Select the style of alarm systems so that their appearance is in harmony with other architectural elements of the historic building.
- Install fire extinguishers without the permanent alteration of the appearance of the historically significant building fabric.
- Use recess mounted fire extinguisher cabinets where possible.
- Select a fire cabinet style that is least obtrusive to the surrounding historic fabric.
- Locate fire alarms where routing of conduit will not permanently alter the building.

Figure 22 11-1
Dry Pipe exposed fire sprinkler systems can be installed very cost effectively.

CONSIDERATIONS FOR USING AUTOMATIC FIRE SPRINKLER PROTECTION:

- **Approach:** (U.S. General Services Administration 2014) A fire sprinkler system is an integrated system of underground and overhead piping with independent sprinkler heads for controlling and/or extinguishing a fire. All fire sprinkler systems have the following parts:
  - o **Control Valves:** Provide capability of shut down after the fire has been controlled and for periodic maintenance and modification.
  - o **Alarm:** Alerts facility and emergency force when the sprinkler water flow occurs.
    - Alerts building management when a sprinkler valve is closed.
  - o **Drain and test connection:** A drain connection is installed to remove all water from a sprinkler system and prevent leakage onto a protected space.
    - Test connection is provided to simulate the flow of water through a sprinkler line, thereby verifying the working condition of an alarm.
  - o **Specialty Valve:** Dry pipe and pre-action sprinkler systems require complex, special control valves that are designed to hold water from the system piping until needed.
  - o **Fire hose connections:** Allow firefighters to supplement sprinkler system with hoses.
  - o **Back Flow Preventer:** Prevents polluted water from going into the potable water supply.
  - o Wet Pipe, Dry Pipe, Deluge and Pre-Action sprinkler systems will be discussed below.
- **Design Consideration:**
  - o Visual Impact. Each piping material will have different visual aspects.
  - o Physical Impact to Historic Fabric. When retrofit work is undertaken, the building will be altered as holes are drilled, walls and ceilings are channeled, and anchors are fastened.
  - o Installation Factors. Each sprinkler pipe material has unique installation requirements, with some materials taking longer to install than others.
  - o Durability. All approved sprinkler pipe materials can be durable; environmental or placement factors can affect the physical impact or corrosion of the material.
  - o Life Expectancy. Certain pipe materials have an inherently longer life expectancy than others - but this can come at an added cost.
  - o Cost. Different system types and their components will have varying costs, which must be weighed against the potential benefits.
  - o Analysis is required to determine which type of Fire Protection System will benefit a historical building without compromising its character.

Figure 22 11-2 Fire Alarm

Figure 22 11-3 Fire Connection

Figure 22 11-4 Backflow preventer

CONSIDERATIONS FOR USING AUTOMATIC FIRE SPRINKLER PROTECTION continued:

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - If existing fire lines/pressure do not meet the required calculations, a booster pump will be required to boost the water pressure up to meet the demand.
    - This will require a pump house which will alter the historic look.
  - If water lines must be exposed, there can be methods to conceal the piping.
    - Furring of the walls.
    - Painting the piping to match existing ceiling and walls.
    - Recessed cabinets.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - There is no appreciable energy savings by having or not having a sprinkler system in comparison to another fire suppression system.
  - The considerations of how the actual system works in conjunction with the historic building far outweigh considerations of energy savings and should have an equal footing with the cost considerations.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Since these systems must be custom designed to the specific situation of a building, these Guidelines can only provide a potential square foot cost.
  - Using municipal water systems, average about $0.33 per square foot.
  - See the cost comparison table on page 177 for more information.

Figure 22 11-5
Dry sprinkler sub-zone on the front porch of a historic building.

CONSIDERATIONS FOR USING AUTOMATIC FIRE SPRINKLER PROTECTION continued:

- **Approach DRY PIPE:**
  - Dry pipe –filled with pressurized air or nitrogen, rather than water.
    - This air holds a remote valve, (dry pipe valve) in a closed position.
    - This valve prevents water from entering the pipe until a fire causes one or more sprinklers to operate.
    - Once activated, the air escapes and the dry pipe valve releases, allowing water to enter the pipe and discharge onto the fire.
  - **PROS**
    - Provide automatic protection in spaces where freezing is possible.
      - Typical installations include unheated warehouses and attics, outside exposed loading docks and within commercial freezers.
    - Advantageous for protection of collections and other water sensitive areas.
      - This perceived benefit is due to a fear that a physically damaged wet pipe system will leak while dry pipe systems will not.
      - The system will generally not offer any advantage over wet pipe systems.
  - **CONS**
    - Increased complexity: Require additional control equipment and air pressure supply components which increase system complexity.
    - Without proper maintenance, dry pipes may be less reliable than wet pipe systems.
    - Higher installation and maintenance costs because of added complexity.
      - Higher costs are primarily due to added service labor costs.
    - Lower design flexibility: strict requirements regarding the maximum permitted size (typically 750 gallons) of individual dry-pipe systems.
      - Limitations may impact the ability of an owner to make system additions.
    - Increased fire response time: Up to 60 seconds may pass from the time a sprinkler opens until water is discharged onto the fire.
      - Delay fire extinguishing actions, which may produce increased content damage.
    - Increased corrosion potential: Following operation, systems must be completely drained and dried. Otherwise remaining water may cause pipe corrosion and premature failure.

TYPICAL DRY PIPE SPRINKLER SYSTEM

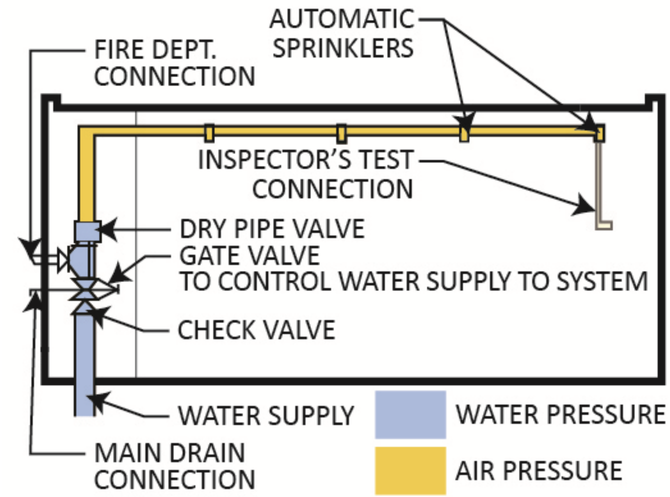


Figure 22 11-6

Figure 22 11-7 Dry Pipe System

CONSIDERATIONS FOR USING AUTOMATIC FIRE SPRINKLER PROTECTION continued:

- **Approach WET PIPE:**
  - Wet pipe systems are the most common fire sprinkler system.
  - Water is constantly maintained within the sprinkler piping. When a sprinkler activates, this water is immediately discharged onto the fire.
  - **PROS**
    - System simplicity and reliability: Least number of components and therefore, the lowest number of items that can malfunction.
      - Reliability which is important since sprinklers may sit many years before they are needed.
      - The aspect of simplicity also becomes important in facilities where system maintenance may not be performed with the desired frequency.
    - Relatively low installation and maintenance expense: Due to overall simplicity, the least amount of installation time and capital is required.
      - Maintenance cost savings: less service time is generally required compared to other system types. These savings become important when maintenance budgets are shrinking.
    - Ease of modification: Advantageous since modifications involve shutting down the water supply, draining pipes, and making alterations.
      - System is pressure tested and restored. Additional work for detection and special control equipment is avoided which again saves time and expense.
    - Short-term down time following a fire: Require the least amount of effort to restore.
      - Sprinkler protection is reinstated by replacing the fused sprinklers and turning the water supply back on.
  - **CONS**
    - Not suited for sub-freezing environments.
    - If piping is subjected to severe impact damage it could consequently leak, thus damaging property.

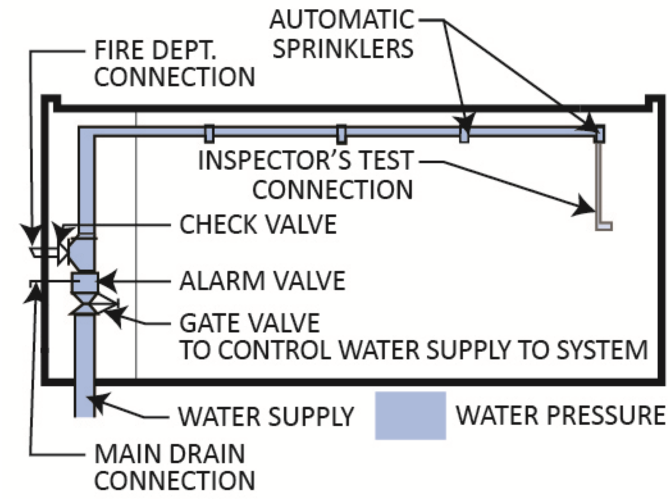


Figure 22 11-8

Figure 22 11-9
Wet pipe system concealed to preserve the aesthetics of the building.

CONSIDERATIONS FOR USING AUTOMATIC FIRE SPRINKLER PROTECTION continued:

- **Approach DELUGE:**
  - Similar to a pre-action system except the sprinkler heads are open and the pipe is not pressurized with air.
  - Connected to a water supply through a valve that is opened by the operation of a smoke or heat detection system.
  - The detection system is installed in the same area as the sprinklers.
  - When the detection system is activated water discharges through all of the sprinkler heads in the system.
  - Used in places that are considered high hazard areas such as power plants, aircraft hangars and chemical storage or processing facilities.
  - Needed where high velocity suppression is necessary to prevent fire spread.
  - **Maintenance Considerations**
    - Fixed temperature releases must be inspected on a regular basis for corrosion, mechanical damage, obstructions, paint, etc.
    - Adequate heat must be maintained around the fixed temperature release and release piping system.
    - Replacing fixed temperature releases: the system must be removed from service.
    - Sprinkler systems that have been subject to fire must be returned to service as soon as possible. The entire system must be inspected for damage and repaired or replaced as necessary.
  - **PROS**
    - Protect extra hazard occupancies that require significant amounts of water to cool and control the growth or development of a fire.
    - Employed on hazards that contain low flash point flammable liquids or hazards with large amounts of combustible liquids.
  - **CONS -** Due to the following procedures, it is not recommended for the Fire Department to restore the system:
    - Water discharges through all of the sprinkler heads in the system.
    - Clapper valve must be manually reset with the latching mechanism in place.
    - Detection system is re-activated.

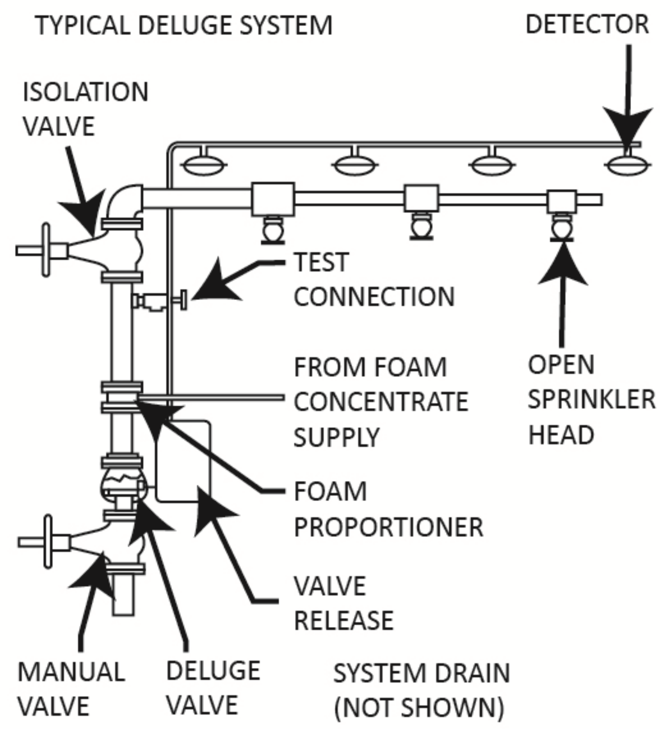


Figure 22 11-10 Image from: incontrolfp.com

Figure 22 11-11
Deluge Sprinkler System

Figure 22 11-12

CONSIDERATIONS FOR USING AUTOMATIC FIRE SPRINKLER PROTECTION continued:

- **Approach PREACTION:**
  - Employ the basic concept of a dry pipe system in that water is not normally contained within the pipes.
  - The difference is that water is held from piping by an electrically operated valve, known as a pre-action valve.
  - Valve operation is controlled by independent flame, heat, or smoke detection.
  - **PROS**
    - The dual action required for water release.
    - Valves must operate and sprinkler heads must fuse.
      - Provides an added level of protection against inadvertent discharge. For this reason, pre-action systems are frequently employed in water sensitive environments such as archival vaults, fine art storage rooms, rare book libraries and computer centers.
  - **CONS**
    - Higher installation and maintenance costs.
      - Pre-action systems are more complex with several additional components, notably a fire detection system. This adds to the overall system cost.
    - Modification difficulties.
      - Specific size limitations may impact future system modifications.
      - Modifications must incorporate changes to the fire detection and control system to ensure proper operation.
    - Potential decreased reliability.
      - The higher level of complexity creates an increased chance that something may not work when needed.
      - Regular maintenance is essential to ensure reliability.

Figure 22 11-13 Pre-Action valves, Image from: hfmplanreview.org

CONSIDERATIONS FOR USING A CHEMICAL FIRE SUPPRESSION SYSTEM:

- **Approach:**
  - Carbon Dioxide, Clean Agent, Dry or Wet Chemical, and alternative agents to replace halon systems are special systems that individual department operations require to protect their equipment, which is sometimes an alternative to using a fire sprinkler system.
    - Condensed aerosol systems use four methods to put out the fire:
      - Reduction or isolation of fuel, reduction of heat, reduction or isolation of oxygen, and inhibiting the chemical reaction that creates the fire.
    - PROS: Flexible and cost effective means of extinguishment.
      - Extinguished with one-fifth the amount Halon 1301 needed to complete the same process.
    - CONS: It has not been listed as safe to use in occupied spaces.
  - Carbon Dioxide System: Fast, efficient and adaptable to a wide range of hazards, the discharge of carbon dioxide [a low-cost clean agent] is non-damaging to property and electrically non-conductive.
    - PROS: Effective in suppressing Class B flammable liquid and gas fires.
    - CONS: Carbon dioxide has adverse effects for people.
  - High expansion foam system:
    - PROS: Foam smothers the fire, suffocating the oxygen supply, and extinguishing the fire.
      - Forms a flooding layer of air-filled bubbles in areas with containment barriers.
    - CONS: Best used only in small areas.
  - Low expansion foam system:
    - PROS: Foam coats the Class B fire source, isolating it, and cooling the source.
    - CONS: Only effective with two-dimensional fires.
  - Clean agent system: Gaseous fire suppression, use inert gases and chemical agents.
    - Chemical agents release gases that extinguish the fire, and inert gases lower the oxygen in the area to control the blaze.
    - PROS: Foam coats the Class B fire source, isolating it, and cooling the source.
    - CONS: Only effective with two-dimensional fires.

Figure 22 11-14 Dry Chemical Fire Extinguishing System

Figure 22 11-15 Clean Agent System

Figure 22 11-16 Clean Agent System,

GUIDELINE DESCRIPTION: This Guideline will discuss adding solar hot water heating systems, heat pump tank-type water heaters, tankless hot water system recommendations, hot water recirculation systems, piping locations (baseboards versus ceilings), and piping insulation. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 00 03 Major Preservation and Energy Issues
- 07 31 Insulation for Sloped Roofs
- 07 51 Insulation for Flat Roofs
- 26 01 Solar Photovoltaic Panels

GENERAL NOTES: Hot water piping should be insulated to increase energy efficiency.

CONSIDERATIONS FOR SOLAR HOT WATER SYSTEMS:

- **Approach:**
  - Components:
    - Water storage tank with internal heat exchanger.
    - Solar panels.
    - Piping – New supply and return loop piping that connects the storage tank to the solar panels is required. Routing can be difficult in an existing historic building, depending on the specific building and the distances pipes need to travel from the mechanical room to rooftop.
      - Can be possible to reuse existing piping from water heater room to fixtures
    - Controls.
    - Supplemental electric or gas hot water heater.
      - Recommended to ensure sufficient hot water early in the day since the solar system cannot keep the water hot at night or on cloudy days.
  - Freeze-protected circulating fluid flows from the solar panels through the heat exchanger to warm the water in the storage tank.
    - Ordinary water can be used if it is drained to a tank at night to prevent freezing.

Solar Hot Water System Diagram

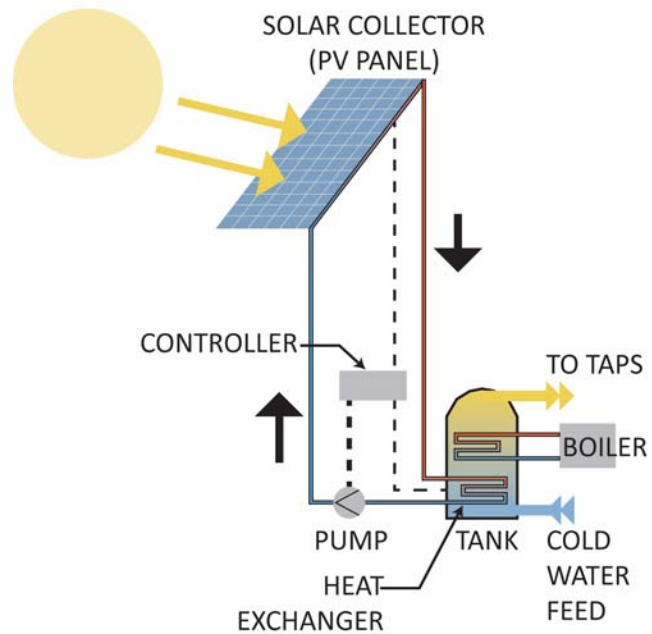


Figure 22 33-17

CONSIDERATIONS FOR SOLAR HOT WATER SYSTEMS continued:

- **Approach continued:**
  - Solar Hot Water systems are not difficult to install, especially in a building with sufficient mechanical room space, available rooftop area, and space to route piping. Depending on climate, the systems can require overheating protection.
  - Solar hot water panels are 50-70% efficient compared to <20% efficient for photovoltaic panels. Therefore, more solar energy can be captured in a hot water system than in a photovoltaic system for the same solar panel area.
  - There are two main panel types: Discuss with the Design Team for a specific project.
    - Flat-plate collector: durable design due to tempered glass.
    - Vacuum tube collector: can heat water up to higher temperatures than a flat-plate, and can replace individual tubes.

- **Secretary of Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - Roof mounted solar panels are not often recommended by CRM or SHPO on a sloped roof unless they are on a very minor elevation of the building, and are not visible from a major elevation.
  - Roof mounted panels may be appropriate on flat roofs if there is a surrounding parapet tall enough to hide them from any major view of the building. Panels are most effective if they are sloped to be more closely perpendicular to the sun's rays. The slope may have to be reduced if a historic parapet is not high enough to hide it at optimal slope.
  - Ground mounted panels can be hidden from view with landscaping or an appropriately designed fence. The fence/landscaping must not shade the panels.
  - Heated fluid from ground mounted panels can lose heat with distance from the building; so, closer is better for efficiency.

Construction photographs of the Solar Hot Water Install. Installation and piping is very similar to conventional hot water systems. Access for routing is of primary concern in historic buildings.

Figure 22 33-18 Overhead, insulated hot water pipes

Figure 22 33-19
Storage tank and piping in the mechanical room

CONSIDERATIONS FOR SOLAR HOT WATER SYSTEMS continued:

- **Historic Preservation Effects continued:**
  - Hot water tanks can be located in basements or other areas designated for mechanical equipment. The closer to the point of use, the better for efficiency.
  - Piping will need to be hidden from view in interior rooms.

- **Energy Efficiency Potential:**
  - Solar hot water systems greatly reduce electric or gas energy usage at the hot water tank but add a small energy load for the pump and controller.
  - A typical design could satisfy about 80% of the hot water requirement for a commercial building.
  - A small solar hot water system could save 4,000 kWh per year compared to a conventional electric water heater, or 300 therms per year compared to a gas water heater.

- **Cost Considerations:**
  - Moderately sized solar hot water systems can cost $6k-$8k but are becoming less expensive as manufacturers increase production of the systems.
  - A 40 gallon energy star certified electric hot water tank costs an average of $500/year to operate. An 80% reduction in energy cost would be $400/year, meaning a simple payback on a $7k solar hot water system would take 17 years.
  - A 40 gallon energy star certified gas hot water tank costs an average of $294/year to operate. An 80% reduction in energy cost would be $235/year, meaning a simple payback on a $7k solar hot water system would take 30 years.
  - Specific payback periods are dependent on the efficiency of the existing water heater and the cost of adding solar water heating to the existing building.

Figure 22 33-20

Figure 22 33-21

2 PV panel installations for Solar Hot Water Systems on new facilities. Notice the angle of the panels; this would probably not be approved for a historic project. A lower panel angle might result in more panels being required. Top: Thomas Bell Community Center, Bottom: Gerald Martin office building, both in Albuquerque, NM.

CONSIDERATIONS FOR TANK-TYPE HEAT PUMP WATER HEATERS:

- **Approach:**
  - Components: A heat pump water heater looks like a typical electric tank-type water heater.
    - Typical electric water heaters connect to 208V single phase electrical, and heat pump water heaters have the same requirement
  - Heat pump type water heaters are over twice as efficient as standard electric water heaters. They operate on the refrigeration cycle by transferring heat from the surrounding air into the water more efficiently than typical heating elements.

- **Energy Efficiency Potential:**
  - Heat pump type water heaters can save over 2,500 kWh of energy per year compared to a standard electric water heater which uses over 5,000 kWh per year.

- **Cost Considerations:**
  - Energy Star lists the electrical cost of a typical electric water heater at $520 per year, and a heat pump type water heater at $230 per year for a savings of $290 per year.
  - Heat pump type water heaters were only introduced to the mainstream market recently and are two to three times more expensive than a standard water heater. A life cycle cost analysis can be done to determine payback period. Due to the high electric bill savings, the payback period will likely be less than four years.

HEAT PUMP WATER HEATER

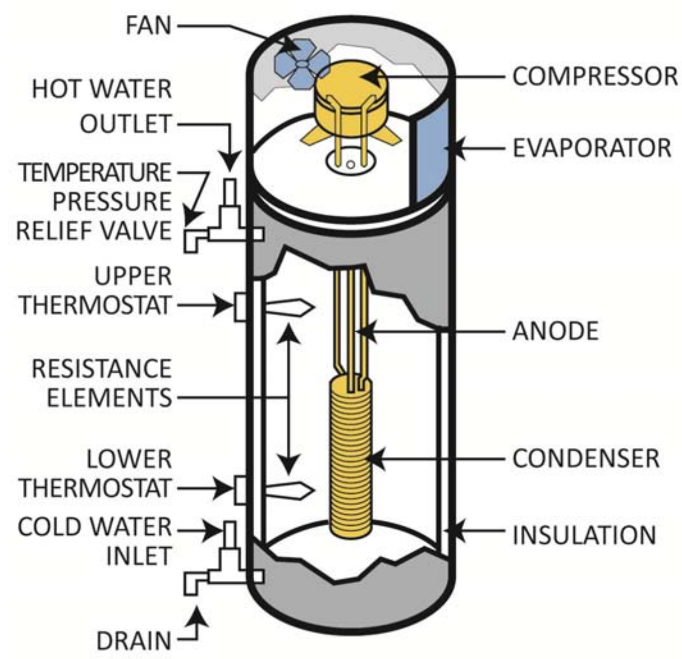
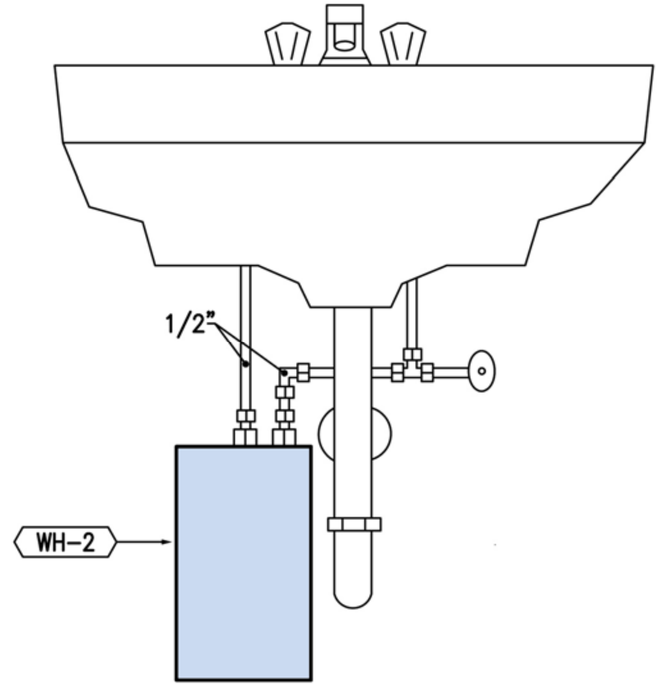


Figure 22 33-22

CONSIDERATIONS FOR TANKLESS HOT WATER SYSTEMS:

- **Approach:**
  - Determine whether or not a tankless hot water system is feasible for a specific project:
    - How many fixtures require hot water?
    - What flowrate (gallons per minute or GPM) will be required?
    - Water heaters are sized based on flowrate and the temperature rise required, since it requires less energy to heat water 40 degrees rather than 60 degrees.
  - Advantages:
    - Can reduce energy usage. Instead of continually maintaining a tank of hot water, a tankless system heats water as it is needed.
    - Takes up much less space than tank-type.
  - Disadvantages:
    - Require higher bursts of energy (electric or gas) than tank-type heaters because they have to heat the water up as quickly as possible, rather than being able to use energy at a slower rate and storing the water as it warms up.
    - Has to mix hot water with cold water to deliver the right temperature at the fixture, so the hot water temperature at the fixture is less consistent than with a tank type.
  - Gas vs. Electric: Gas tankless water heaters are more common than electric because the electric models can require service upgrades to meet power requirements. Electric units generally require power other than 120V single phase. For example, a 3 GPM unit (enough for a shower or tub and faucet) requires as much power as three (four-ton) HVAC units.
  - Small tankless electric units that deliver only enough hot water for one or two sinks can operate off a 120V wall outlet, and may be a good solution for a building with an existing hot water tank located a long distance away from a new restroom.
  - Maintenance: Tankless water heaters require maintenance to prevent scale buildup and are more susceptible to hard water. If a building has hard water and tankless heaters are going to be used, a water softener is required. Tank-type water heaters have sacrificial anodes to prevent scale buildup on the tank and element, but the water heaters can still eventually become scaled and require replacement.

TANKLESS HOT WATER SYSTEM INSTALLED UNDER SINK



NOTES:

1. PROTECT WATER HEATER FROM EXPOSURE TO DAMP, HUMID AND FREEZING CONDITIONS.
2. WATER HEATER MUST BE INSTALLED TO CONFORM WITH CURRENT NATIONAL ELECTRIC CODE, AND ANY APPLICABLE LOCAL PLUMBING, ELECTRICAL, HEATING AND AIR CONDITIONING CODES.
3. FOLLOW MANUFACTURER’S INSTALLATION INSTRUCTIONS.

Figure 22 33-23

CONSIDERATIONS FOR TANKLESS HOT WATER SYSTEMS continued:

- **Secretary of Interior Standards:**
  - 2: Historic Character Preservation

- **Historic Preservation Effects:**
  - Usually these units are located in designated mechanical rooms or in restrooms. These locations rarely have character defining features to be preserved. However, in a few cases, for example, a historic room that is to be used as a conference room with a new coffee bar and sink, a small unit could be placed in the cabinet under the sink.

- **Energy Savings Potential:**
  - Tankless hot water systems can reduce energy usage, especially at infrequently used fixtures, since the water is heated at point-of-use rather than constantly losing heat through the water heater and piping.
  - The US Department of Energy estimates the energy savings potential for tankless water heaters to be about 30% for lower demand installations (40 gal/day) and about 10% for higher demand installations (86 gal/day). (Tankless or Demand-Type Water Heaters 2012).

- **Cost Considerations:**
  - Tankless water heaters are about 50% more expensive than conventional storage water tanks and the payback period can be longer than the expected lifespan. However, in applications with lower demand (<45 gal/day), gas piping, and water that is not too hard, tankless water heaters can be life cycle cost effective.

CONSIDERATIONS FOR HOT WATER RECIRCULATION SYSTEMS:

- Depending upon hot water needs, adding a recirculating hot water system is a possible renovation in a historic structure. However, they have a considerable installation cost and do not use less energy; so, they will not be discussed in this Guideline. Discuss the possibilities of such a system with the Design Team and CRM / SHPO.

Figure 22 33-24
Mechanical Room gas Tankless Hot Water heater

Figure 22 33-25
Mechanical Room electric Tankless Hot Water heater

GUIDELINE DESCRIPTION: First, general information is presented on thermal comfort, building energy usage, natural versus mechanical ventilation, zoning, noise and vibration, ductwork, and life cycle cost. Second, various types of HVAC systems are presented: forced air, centralized versus distributed, constant air volume, variable air volume, fan coil, variable refrigerant flow comparison, split systems, heat pumps, geothermal, two-pipe, and four-pipe systems, including controls. Third, information on how to select an HVAC system is discussed in general terms. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 00 03 Major Preservation and Energy Issues
- 07 31 Insulation for Sloped Roofs
- 07 51 Insulation for Flat Roofs
- 23 11 HVAC Interior Placement
- 23 12 HVAC Exterior Placement
- All of the Guidelines tackle energy efficiency: the higher the efficiency, typically, the smaller the demand on HVAC system. Therefore, all of the Guidelines are related.

GENERAL NOTES:

- **Secretary of the Interior Standards: Applicable for all systems listed under this Guideline**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
- The Energy Efficiency Potential and Cost Considerations for this Guideline do not follow the same format as laid out in previous Guidelines and discussed in the Introduction. HVAC system selection is building specific and highly variable. It is recommended that final selection and cost estimates be done by a qualified engineer.
- When considering different HVAC systems, all systems need to conform to the UFC Series 4 Multi-Disciplinary and Facility Specific Design requirements.

Basic HVAC System Definitions and Concepts:

Forced Air *systems use fans, ductwork, heating and cooling sections to temper and distribute air.*

Variable Air Volume *systems are 'forced-air' but can operate effectively at lower airflows when conditions allow the reducing of energy usage.*

Heating and cooling can use ***refrigerant piping*** *or* ***hydronic heating and cooling water piping*** *instead of ductwork but fans are still used to distribute the heating/cooling air.*

Ventilation *is an important factor in the comfort and safety of building occupants. Ventilation is fresh 'outside air' brought into the space.*

There is no one size fits all HVAC solution. HVAC selection should be done on a building-by-building basis taking specific building factors into account.

HVAC equipment is continually being improved to provide better comfort and use less energy in order to meet or exceed the latest guidelines.

GENERAL NOTES continued:

- Thermal criteria changes: Prior to 1900, the standard for heating was 65-70 deg F (McGuinness, Stein and Reynolds). Today, 65-70 deg F is only borderline comfortable (70-72 deg F is typical). Later in the 20th century after air conditioning was developed, humidity was included as a factor. Higher temperatures are more comfortable at a lower humidity.
  - ASHRAE Standard 55 titled 'Thermal Environmental Conditions for Human Occupancy' considered other factors in addition to temperature and humidity level. (See Chart 23 08-1.)
    - Activity levels (metabolic rate) and clothing levels are added to the criteria.
      - Someone doing sedentary office work feels more comfortable at a higher temperature than someone working out in a gym.
- Building Energy Usage:
  - ASHRAE 90.1 'Energy Standard for Buildings Except Low-Rise Residential Buildings' is a document which lists minimum requirements for energy efficiency. The building envelope, HVAC systems, power and lighting are discussed.
    - In 2005, the US federal government mandated that buildings must be designed to meet ASHRAE 90.1-2004, and new buildings constructed after 2007 should be 30% more efficient than an ASHRAE 90.1-2004 baseline if it is life-cycle cost-effective. (ASHRAE Standard 90.1 2004).
    - Can earn LEED credits for designs that are more efficient than the ASHRAE baseline.
    - Computer modeling programs like Trane Trace and eQUEST provide engineers with ways to compare proposed building energy usage to the ASHRAE baseline.
- Lifecycle cost:
  - Modern energy modeling software (Trane Trace, eQUEST) can calculate the energy requirements of a building on an hour-per-hour basis throughout a year. Various HVAC systems can be modeled and compared and energy usage can be estimated, so that a life cycle cost calculation with capital, energy, and maintenance costs can be used in determination of the best HVAC system to install.

Common Abbreviations used in this Guideline:

AHU *– Air Handling Unit*

ASHRAE – *American Society of Heating, Refrigeration, and Air-Conditioning Engineers*

HVAC *– Heating, Ventilation, Air-Conditioning*

LEED – *Leadership in Energy and Environmental Design*

MAU – *Makeup Air Unit*

RTU *– Roof Top Unit*

SMACNA *– Sheet Metal and Air Conditioning Contractors National Association*

DX *– Direct Expansion (Refrigeration Cycle)*

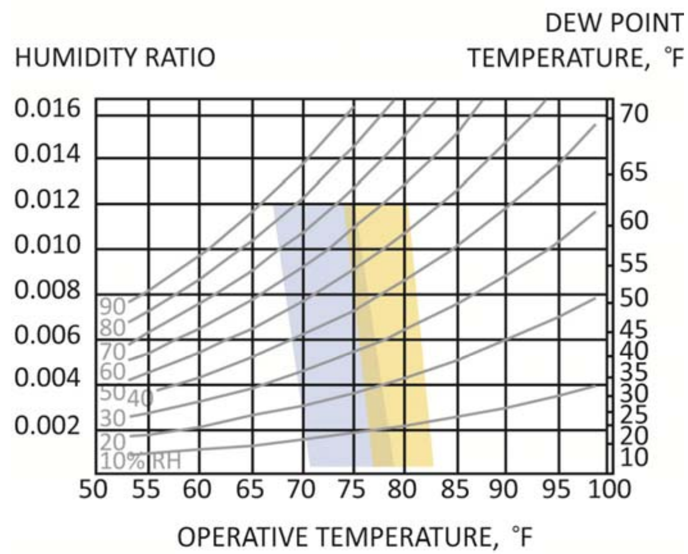
VRF *– Variable Refrigerant Flow*

EER *– Energy Efficiency Ratio*

GENERAL NOTES continued:

- Ventilation:
  - ASHRAE Standard 62.1 specifies the amount of ventilation (outside air) required for various types of spaces.
    - Spaces with operable windows (natural ventilation) can be served by HVAC systems that do not deliver ventilating air, as long as the windows are within 25 feet and can open to 4% of the floor area (refer to ASHRAE Standard 62.1, paragraph 5.1.1) In these cases, ductless split system heat pumps/VRF systems or fan coils that use water can be used because both of these HVAC systems are 100% recirculating.
    - Spaces without operable windows generally require ventilation at about 5 cfm (cubic feet per minute) per person plus 0.06 cfm per sf. (ASHRAE Standard 62.1 2010). This ventilation air can come from a roof top unit (RTU) or air handling unit (AHU) set to a minimum outside airflow or from a 100% makeup air unit with an energy recovery wheel. Makeup air units are used in conjunction with other heating and cooling systems serving the space, like fan coils, radiant floor heating or chilled beam cooling.
- Zoning of HVAC systems is an important factor in user comfort. A higher quantity of zones (thermostats) can lead to greater control and comfort but also comes at a cost.
  - Certain areas should be zoned differently based on building orientation, fenestration and space use.
    - Zone interior rooms together since they have less heat loss/gain to the outside.
    - Zone exterior rooms together because they require more HVAC. Rooms facing south and/or west require more cooling, and rooms facing north require more heating.
    - Rooms should also be zoned according to uses. For example, a conference room that is used a portion of the time should be on a separate zone to reduce energy.
  - Well-designed HVAC zoning improves a building's energy efficiency because the heating and cooling are delivered where needed.
    - For example, if interior and exterior rooms are zoned together, then the exterior rooms can require more heating and cooling to be comfortable than the interior. Too much heating or cooling is delivered to the interior rooms and energy is wasted.

ASHRAE STANDARD 55: Acceptable range of operative temperature and humidity for spaces.



NOTE:
UPPER RECOMMENDED HUMIDITY LIMIT 0.012 HUMIDITY RATIO.
THERE IS NO RECOMMENDED LOWER HUMIDITY LIMIT.

Chart 23 08-1

GENERAL NOTES continued:

- Increased HVAC zoning requires more equipment and installation expense.

- Noise and vibration for HVAC systems:
  - Open ceiling plenums, where air can transfer from above one room to the next room and back to the HVAC equipment, can increase sound transmission from room to room. Walls to deck with air transfer duct elbows and return grille sound boots reduce noise.
  - Interior acoustical lining of certain supply, return, and exhaust ductwork can be an inexpensive way of reducing the noise level. If duct lining is used, it should be non-shedding. Duct elbows, sufficient straight duct into and out of fans, and manufactured silencers can also be an effective means of reducing sound.
  - Vibration isolation connectors and flexible connections can be used to minimize transmittal of vibration from mechanical equipment.
- Ductwork:
  - There are four main types of ductwork in a building.
    - Exhaust ducts – move air from the spaces to the exterior
    - Outside air ducts – duct fresh air through HVAC equipment and into the spaces
    - Supply ducts – move air from HVAC equipment and distribute the air to the spaces
    - Return ducts – deliver air from the spaces back to the HVAC equipment, to be mixed with fresh air and heated/cooled and then redelivered as supply air
  - Insulation – insulate supply and return ductwork located in uninsulated spaces to improve energy efficiency of the HVAC system.
    - The International Energy Conservation Code (IECC) and ASHRAE 90.1 both provide minimum R-values of duct insulation that should be installed.
    - ASHRAE 90.1, IECC, and SMACNA guides provide direction on duct installation including sealing and allowable leakage. Leaky and/or uninsulated ductwork in unconditioned spaces will reduce energy efficiency of the system.
    - Ductwork exposed to the spaces served is commonly uninsulated and does not significantly reduce energy efficiency because the heating and cooling is still transferred to the space. Exhaust and outside air ducts are often uninsulated.

4 MAIN TYPES OF DUCTWORK

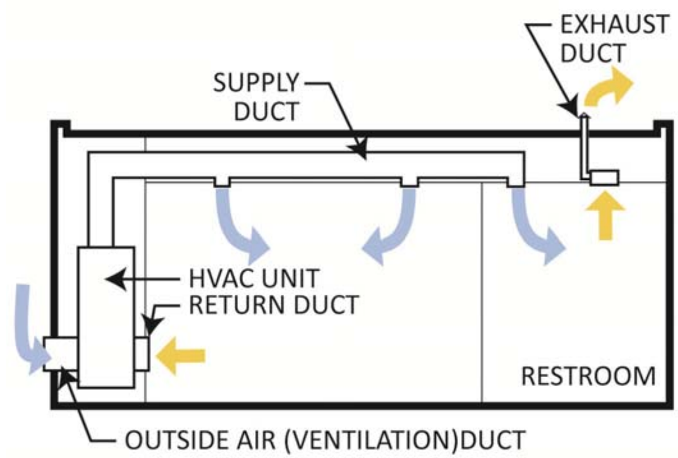
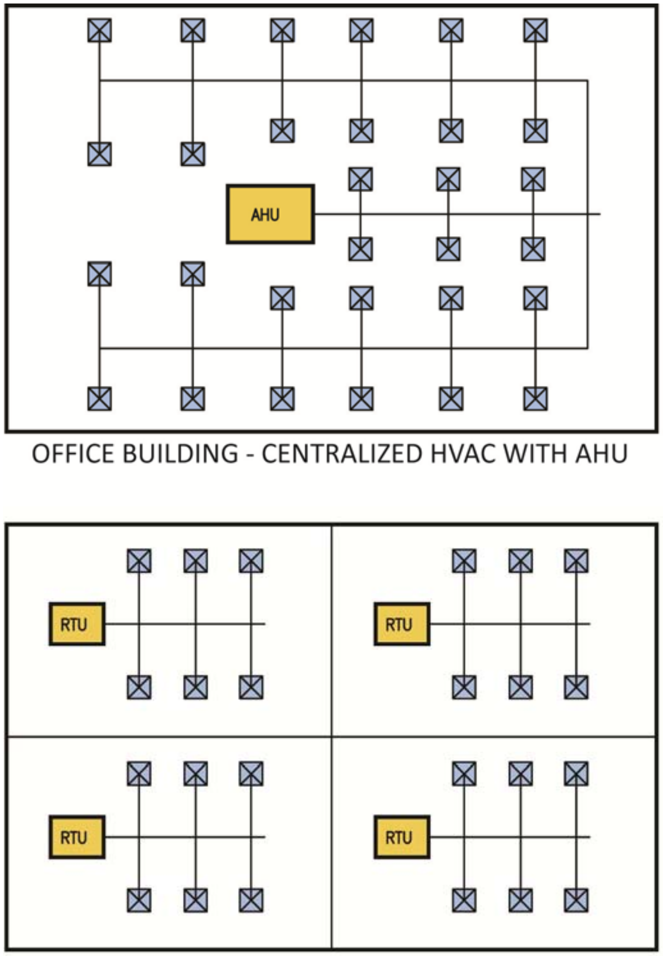


Figure 23 08-1

CONSIDERATIONS FOR FORCED AIR SYSTEMS:

- **Approach:**
  - Centralized or distributed forced air systems
    - Centralized HVAC systems, like a large AHU (air handling unit, either constant or variable air volume) in a central location, generally require larger main ducts because all supply and return air have to connect to one unit.
      - High velocity ducts and variable volume terminals where the air is reduced to low velocity can reduce the supply duct sizes.
    - Distributed HVAC systems like multiple RTUs (roof top units) installed throughout the building provide a certain amount of zoning.
      - Constant volume RTUs/AHUs are at a ratio of one per zone
      - Variable speed RTUs/AHUs with variable volume terminals can have more zones
  - Energy requirements
    - AHUs require electricity for fans, dampers, and controls.
      - Cooling provided by chilled water or DX cooling (direct expansion cycle).
        - Chilled water can be provided from a central plant or be produced at a specific building via an air-cooled chiller or cooling tower/chiller combination.
        - DX cooling utilizes the refrigeration cycle to cool the air. DX cooling can be built into a ‘packaged unit’ or can be provided by a separate exterior condensing unit and evaporator inside the AHU.
      - Heating utilizes natural gas, propane, heated water, electric heat pump or resistance heat.
      - Heat pumps provide cooling like a typical air conditioner but the cycle is reversed for the heating cycle. The equipment can either be air cooled or water cooled. The efficiency of heat pumps drops drastically at lower outside air temperatures and if used in a cold climate supplemental electric resistance heat should be used.



OFFICE BUILDING - CENTRALIZED HVAC WITH AHU

OFFICE BUILDING - DISTRIBUTED HVAC WITH RTUs

Figure 23 08-2

CONSIDERATIONS FOR FORCED AIR SYSTEMS continued:

- **Approach continued:**
  - Constant volume or variable volume forced air systems.
    - Constant air volume (CAV) systems are generally less expensive because variable speed fans and terminal units (which are equipment in the ductwork that can vary the flow of air and also provide additional heating and/or cooling) are not required.
      - Only have one zone (one thermostat) per unit
      - Also have the highest energy usage since the fan never winds down and turns slower to satisfy the heating/cooling load without over-cooling/heating.
        - When a building is occupied, it is required to have ventilation through either windows or HVAC, so a CAV system can be required to run full speed during occupied hours even when heating/cooling are not required.
    - Variable air volume (VAV) systems are tailored to provide airflow where it is needed.
      - Multiple terminal units tap off the main AHU ductwork. Each is connected to a thermostat.
        - Typically, 55 degree air is provided from a VAV AHU and the air is reheated as needed at the VAV terminal via a hot water coil or electric heat.
          - Where hot water coils are used, associated piping and heating equipment (boilers, heat pumps, etc.) are also required.
        - Rooms can have their own thermostats, or multiple rooms can be connected to the same thermostat and terminal unit.
        - The increased equipment requirements translate into increased cost.
        - VAV systems typically use less energy than CAV systems because the AHU fan speed is adjustable to provide only the amount of heating/cooling and ventilation required.

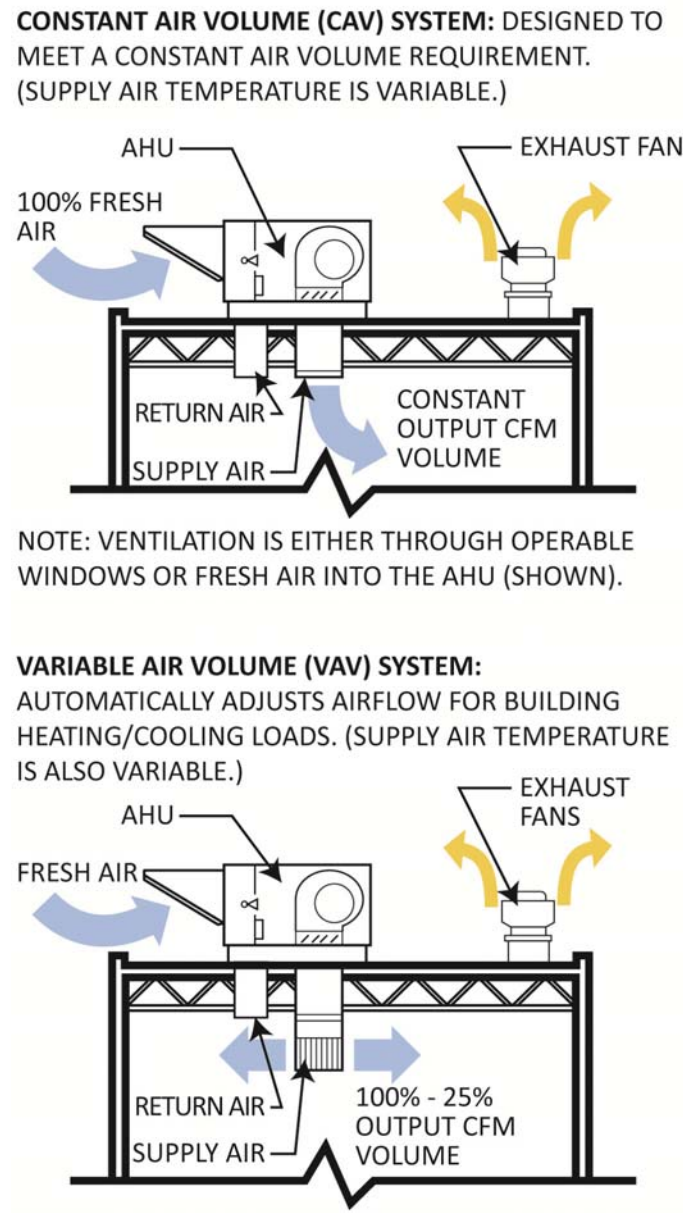


Figure 23 08-3

CONSIDERATIONS FOR FORCED AIR SYSTEMS continued:

- **Historic Preservation Effects:**
  - Existing ductwork in buildings may be reused to reduce the amount of demolition required. However, the duct sizes may not be the optimum dimensions. More often, the location where the original ductwork ran may be appropriate for new ductwork. Roof top units (RTUs) are not often recommended by CRM or SHPO on a sloped roof unless they are on a very minor elevation of the building, not visible from a major elevation.
  - Roof top units (RTUs) may be appropriate on flat roofs if there is a surrounding parapet tall enough to hide them from any major view of the building.
  - Buildings with sloped roofs often have attic spaces. If proper ventilation can be provided to the attic, AHUs can be located there.
  - Ground mounted units can be hidden from view with landscaping or an appropriately designed fence. The fence/landscaping must allow for air intake and heat disbursal from the unit. Ground mounted units need to be very close to the building to avoid a loss of efficiency in delivering the conditioned air.
  - Ducts can be located in basements and existing chases to reach upper floors. When there is no basement or chases connecting upper floors, new furred out areas must be created to locate horizontal ducts. Some alternatives include furring down a portion of the ceiling, or a portion of a hallway. Vertical chases can be furred out in inconspicuous corners of rooms, or in former closets or other utility spaces.
  - Fresh air intakes can be located where historic attic vents were located or where under-floor vent openings existed.
  - When historic buildings receive new heating systems, some CRMs/SHPOs prefer that historic heating fixtures (fireplaces, radiators, etc.) remain to exhibit the way the room appeared.

Ft. Stanton, New Mexico

Figure 23 08-4

Figure 23 08-5

As part of the Historic Renovation of this building, new fresh air vents were added. The half dome, slotted vent style was compatible to other, historic vents found on buildings throughout the site.

CONSIDERATIONS FOR FORCED AIR SYSTEMS continued:

- **Energy Efficiency Potential:**
    - Well-designed forced-air systems, installed properly and using efficient components, can be energy efficient.
        - Energy efficiency can be improved by using variable air flowrates, zoning similar spaces together, or even using geothermal energy.
    - Manufacturers continue to improve the energy efficiency of rooftop equipment. For example, Daikin McQuay has a new 'Rebel' model that uses half the energy of current standards.
    - Electric resistance heat should be used a minimal amount to increase the energy efficiency.

- **Cost Considerations:**
    - Forced air is the most common form of HVAC because of its flexibility, efficiency potential, and cost.
        - CAV systems are the least expensive to install.
        - VAV systems are about 50% more expensive than CAV systems but provide better efficiency and zoning capability.
    - Equipment with higher energy efficiency typically has a higher first cost but can pay back and provide long term savings. A life cycle cost calculation can be performed to determine the payback period once all of the project variables are known.

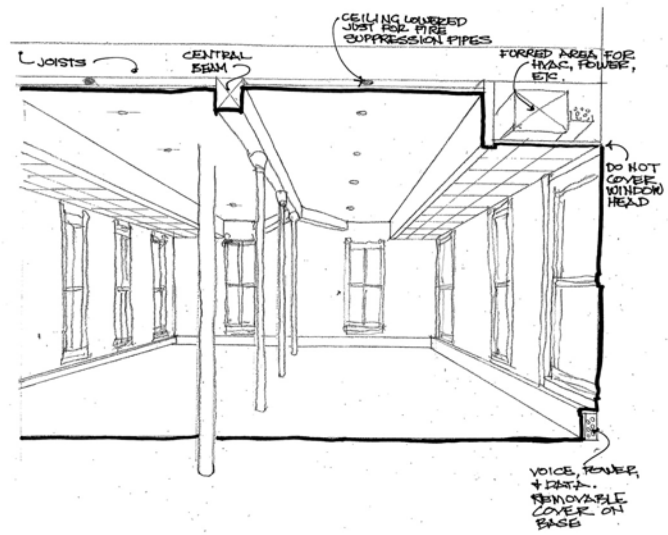


Figure 23 08-6
Sketch of new soffit for the Forced Air HVAC system in a historic structure at Ft. Bliss, El Paso, TX

CONSIDERATIONS FOR FAN COILS AND DUCTLESS SPLIT SYSTEMS:

- **Approach:**
  - Fan coils (FCs) are small terminal units with a powered fan and heating and/or cooling coils.
    - FCs recirculate the air in the space and typically add heating/cooling to the air through chilled/hot water coils, or through variable refrigerant flow (VRF) with refrigerant piped to the terminal unit rather than hot/cold water.
    - FC systems require far less ductwork than forced air systems because the air is recirculated/heated/cooled locally.
      - If chilling/heating water coils are used, then associated piping/chillers/boilers are also required.
      - A VRF system is basically a more complicated 'ductless split system,' and the arrangement uses less interior space for ductwork but adds refrigerant piping.
    - Fan coil/VRF systems can have many zones (thermostats).
  - Ductless split systems operate on electricity and do not use heating/cooling water.
    - Ductless split systems consist of one or multiple indoor fan-coil type unit(s) connected to an outdoor condensing unit with refrigerant piping in between.
    - Split systems can provide cooling-only or cooling and heating (like a heat pump).
    - They are often used to cool computer server rooms since the space requires cooling only without ventilation (outside air), but they can also be used for other purposes where ventilation is through a separate system or operable windows.
  - When ventilation is required, small ducts served by an Energy Recovery Ventilator (ERV) or Makeup Air Unit (MAU) are connected to the FC or VRF terminal.
    - An ERV supplies outside air but recovers the energy (hot or cold) from the air leaving the space. Outside air (ventilation) ducts are connected to the VRF terminal, and exhaust air is ducted out of the space through the ERV. A heat wheel recovers the energy of the leaving air and transfers it to the ventilation air.
    - A MAU provides slightly tempered ventilation air to the FCs and VRF terminals. The ventilation air is a small percentage of the recirculated air and does not need to be heated or cooled to a large extent before going to the FC or VRF terminal.

DUCTLESS SPLIT SYSTEM DIAGRAM

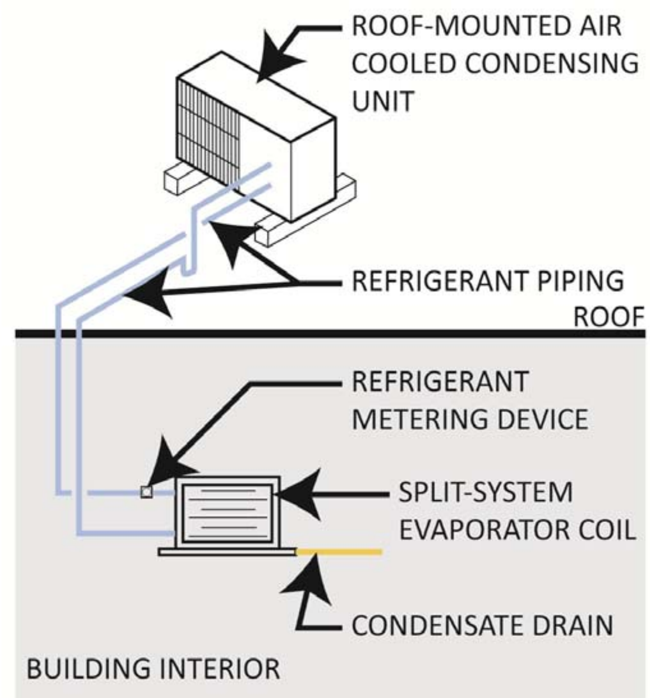


Figure 23 08-7

Figure 23 08-8
Installed Fan Coil VRF unit

CONSIDERATIONS FOR FAN COILS AND DUCTLESS SPLIT SYSTEMS continued:

- **Historic Preservation Effects:**
  - Fan coils and ductless split systems require a minimal amount of interior space and they can be either furred-in or exposed. However, the equipment does require refrigerant or water (hydronic) piping from the boiler/chiller or exterior condensing unit.
  - Condensing units can be located on flat roofs if there is a surrounding parapet tall enough to hide them from any major view of the building.
  - Ground mounted condensing units can be hidden from view with landscaping or an appropriately designed fence. The fence/landscaping must allow for heat disbursal from the unit. Ground mounted units need to be very close to the building to avoid a loss of efficiency in receiving and delivering the piped fluid.
  - Condensers can be located in attics if there is sufficient ventilation.
  - Fan coil units can be located and screened in locations where historic boiler radiator units were housed.
  - Existing penetrations can be reused, but not enlarged. If new holes are required they should be below grade and all penetrations must be made water tight upon completion of the work.
  - Limit the number of units around a building so as not to clutter the landscape.

Figure 23 08-9
VRF and Makeup Air Unit on Roof

Figure 23 08-10
Old Terminal Building, Albuquerque International
Sunport, New Mexico

CONSIDERATIONS FOR FAN COILS AND DUCTLESS SPLIT SYSTEMS continued:

- **Energy Efficiency Potential:**
  - Fan coils and ductless split systems can be energy efficient because the air is circulated a minimal amount compared to forced air systems.
    - Instead of the air needing to return back to an AHU or RTU to be conditioned, the air is just circulated through the fan coil or split system unit inside the room.
    - Fan coil efficiency depends on the heating and cooling equipment for the four-pipe system more than on the fan coils themselves.
      - Boilers can range from 80% up to 95% efficient, meaning the most efficient boilers can reduce gas utility costs by 20%.
      - Air cooled chillers generally have efficiency around 10 EER.
    - Ductless split systems often have an EER of 12-13 compared to about 10 for standard forced air units.
  - ‘Heat Recovery’ VRF systems are unique in their ability to transfer heating or cooling from one zone to another with a minimal amount of electricity input.
    - For example: 6 VRF terminal units are connected to 1 condensing unit. If 4 units are calling for heating and the other 2 calling for cooling, the cooling ‘taken in’ by the four units in heating mode is transferred to the two rooms that need cooling.
    - ‘Heat Recovery’ VRF systems often have an EER of 15 or higher compared to about 10 for standard forced air units. The reduced fan energy of a VRF system can lead to half the energy usage of a forced air system.

- **Cost Considerations:**
  - VRF systems can be the most expensive to install but also the most energy efficient. A life cycle analysis can be performed to show how long the payback period is.
  - As with forced air systems, equipment with higher energy efficiency typically has a higher first cost but can pay back and provide long term savings.

Figure 23 08-11
Pad Mounted Ductless Split Condensing Unit

Figure 23 08-12
Roof-Mounted Air Cooled Condensing Unit,

Figure 23 08-13 Interior Split-System Evaporator Coil,
For Figures 23 08-11 & 12, see diagram on page 200 for component locations.

CONSIDERATIONS FOR GEOTHERMAL HVAC SYSTEMS:

- **Approach:**
  - Geothermal heat pump systems use the ground as a stable-temperature 'heat sink' that can absorb or reject heat to/from a circulating fluid, such as water.
    - The earth, at around 55-60 deg F, can absorb heat from fluid above that temperature and transfer heat into fluid below that temperature.
    - Geothermal heat pump systems boost or lower the temperature of the fluid and provide heating/cooling to a building.
      - Use a water/glycol mix when chilled water is expected to go below freezing.
  - Use either a vertical borefield with wells, or horizontal trenches for piping.
    - The borefield or trenching size requirements vary with the size of the geothermal system, determined by the energy model for the heating/cooling required in the building and the soil test data.
    - If more land area is available and the soil temperature up near the ground level is stable enough, then a horizontal borefield could be more cost effective.
    - If the borefield needs to take up less land, a vertical arrangement can be used.
      - Borefield depth varies by geographic location.
    - A borefield can be installed under a parking lot, accessed by simple manholes.
    - Trenches can also be installed under a parking lot, but are more difficult to access.
  - Geothermal systems can be open loop or closed loop.
    - Closed loop systems recirculate the same fluid through the system and use heat transfer between plastic piping/grout and the earth.
    - Open loop systems bring in fluid from a body of water, extract or reject heat into the fluid, then discharge the fluid back into the body of water. The body of water must be clean and regulations regarding groundwater discharge must be met.
  - The piping can run in a parallel or series configuration (two-pipe or four-pipe).
    - If the piping is in series then the field temperature can be more uneven.
    - The best configuration for a certain project can be determined by an engineer specializing in geothermal systems.

GEOTHERMAL HEAT PUMP SYSTEM (HEATING CYCLE)

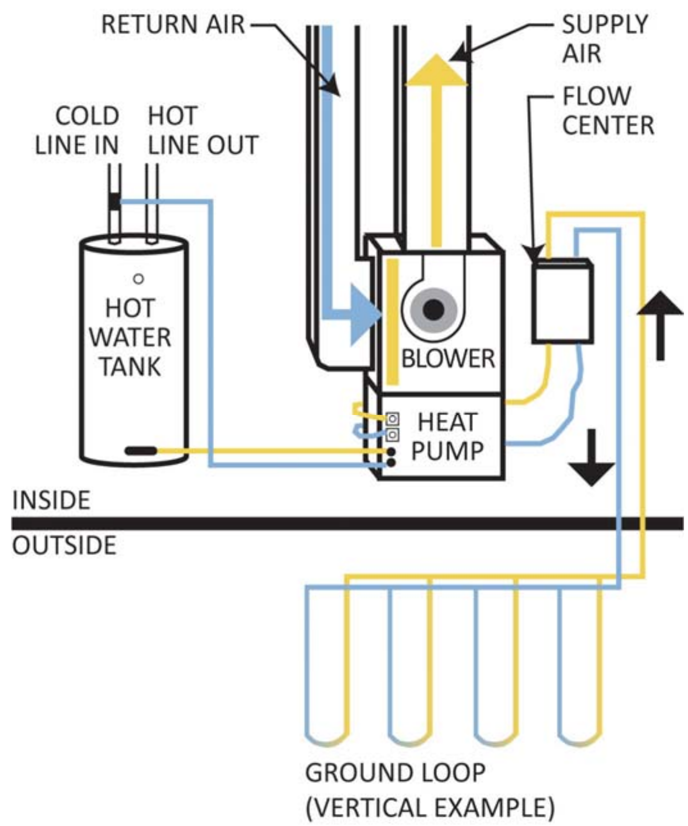


Figure 23 08-14

Figure 23 08-15
Geothermal piping in Trinity Church, Boston, MA

CONSIDERATIONS FOR GEOTHERMAL HVAC SYSTEMS continued:

- **Historic Preservation Effects:**
  - Geothermal equipment can preserve the exterior look of a historic building because the heat transfer is to/from the earth rather than to/from the atmosphere around a building.
  - These are very quiet systems with minimal vibration. Therefore, they can be a good option for buildings in which there are noise related concerns.
  - Since Geothermal HVAC systems can be used with AHUs, or piped fluids, the interior impacts are similar to those noted with these systems above.

- **Energy Efficiency Potential:**
  - Geothermal heat pumps are typically 30% more efficient than air-source heat pumps and geothermal heat pump systems can have low energy usage similar to VRF systems.
    - The geothermal aspect of the system is only part of the equation. The efficiencies of the heat pump and water pumps and heating/cooling equipment like air handlers and fan coils are as important as the geothermal field.

- **Cost Considerations:**
  - Geothermal systems are at least 30% more expensive than conventional air-cooled systems, but because of their greater efficiency they can have long-term cost savings.
  - A life cycle cost analysis should be performed to compare the options since the cost of geothermal systems vary greatly based on geographic location.

Figure 23 08-16
Heat pumps and blowers at Trinity Church

Figure 23 08-17 Supply/return diffuser carefully incorporated into historic fabric of Trinity Church.

CONSIDERATIONS FOR TWO-PIPE RADIANT HEATING:

- **Approach:**
  - Two-pipe radiant heating systems provide supply and return piping for heating water circulation through a radiator.
    - A building with a two-pipe radiant heating system can only provide heating because radiant cooling is largely ineffective.
      - The system could be changed from radiators to fan coils that could provide heating or cooling.
        - Two-pipe systems restrict the zoning of a building, since different zones cannot be heated **and** cooled at the same time.
      - A two pipe system could also be upgraded to a four pipe system with fan coils, so that the fan coils could be in either heating or cooling mode and provide temperature zoning.
    - Ventilation is an important consideration with two pipe and four pipe systems. Operable windows or dedicated outside air systems should be provided to ensure adequate ventilation.

- **Historic Preservation Effects:**
  - Existing heating/cooling water piping can generally be reused. However, upgrading a two-pipe system to a four-pipe system requires additional piping and equipment.
  - See Historic Preservation Effects for Fan Coils and Ductless Split Systems for additional effects. These systems are similar in that they all use piping.

- **Energy Efficiency Potential:**
  - The energy efficiency of a two-pipe or four-pipe system is determined by the boilers, chillers, or heat pumps that heat and cool the water rather than the piping itself (although the piping should be insulated to reduce energy loss).

- **Cost Considerations:**
  - As is the case with other HVAC equipment, high efficiency boilers, chillers, and heat pumps are typically more expensive.
  - A life cycle cost analysis should be performed to compare the options.

Figure 23 08-18
Historic steam radiator for a Two-Pipe Radiant Heating system. Not only can the radiator be reused, but it also might be considered a character-defining feature. If steam radiators are present in the building being renovated, discuss option with the Design Team and CRM/SHPO.

CONSIDERATIONS FOR SELECTING THE BEST CONTROL SYSTEM FOR THE HVAC SYSTEM:

- **Approach:**
  - Control systems for HVAC can be very simple or very complex. Simple controls can be easier to operate but lead to higher energy usage while complex control systems can be expensive to install but can also have user-friendly interfaces and reduce energy usage.
    - **Simplest** – Install a basic thermostat, with manual input to set room temperature.
    - **Simple** – Install programmable thermostats, which are common, inexpensive, and allow the temperature setpoint to be programmed with a ‘setback’ temperature for unoccupied or night periods. Automatic setback thermostats are required in most of the current energy codes (like IECC 2009).
    - **Complex** – Building automation systems (direct digital controls) have room temperature sensors instead of thermostats and allow remote viewing and programming of the temperature setpoints.
      - Well-designed control systems can operate the HVAC equipment most efficiently as parameters change (like outside air temperature and CO2 levels).
      - Sensors can be equipped with an LCD screen and allow a manual override.
      - The control system can be tied into sensors and controls on the HVAC equipment to run the equipment most efficiently, monitor the equipment and send an alarm if anything abnormal occurs.
      - Examples
        - In a LEED building that requires a certain amount of ventilation, an airflow sensor on the outside air duct can send a signal to the building automation system so that the current ventilation flow can be viewed through a web interface. An alarm can be sent if it is below setpoint.
        - HVAC filters can be monitored and send an alarm when they are dirty. New filters have less resistance to air movement and save fan energy.
  - The control system capabilities depend on which type of HVAC system is installed and which parameters can be ‘controlled.’ For example, a VAV air handler requires motorized dampers on the outside air intake for the control system to adjust outside air. VRF systems have built in complex control systems, and the controls can be left ‘standalone’ or tied into a webpage interface.

Figure 23 08-19
Basic Thermostat

Figure 23 08-20
Programmable Thermostat

CONSIDERATIONS FOR CONTROL SYSTEMS continued:

- **Historic Preservation Effects:**
  - Building automation systems requires sensors, controls, wiring, and computers. These components require a certain amount of space and should not be conspicuously placed.
  - See Historic Preservation Effects for Fan Coils and Ductless Split Systems for additional effects. These systems are similar in that they all use piping.

- **Energy Efficiency Potential:**
  - Basic thermostats typically lead to higher energy usage since people do not set back the temperature at night. Simple thermostats are now obsolete for most new HVAC installations because they do not meet current energy codes.
  - Programmable thermostats can automatically setback the temperature and are required for most HVAC systems per the International Energy Conservation Code.
  - Building automation systems allow remote monitoring and viewing of HVAC setting. Large organizations which have temperature setpoint standards can verify that the standards are being met and that people are not setting the thermostat to be warmer or cooler than the standards which would lead to excessive energy use.
    - Some control systems also monitor the actual energy usage (kWh) of specific HVAC equipment so the equipment can be monitored for excessive energy use and the system can be optimized.
    - Variable speed drives are often installed with control systems which allow fans to run at slower speeds when conditions allow, reducing energy usage and providing equal occupant comfort.

- **Cost Considerations:**
  - Building automation systems range from simple and less expensive to highly advanced and costly. Advanced systems lead to higher energy efficiency through increased knowledge of the HVAC equipment performance and controllability. Programmable thermostats are less than $100, and building automation systems costs vary widely but start around $1.50 per square foot.

BUILDING AUTOMATION SYSTEM DIAGRAM WITH POSSIBLE COMPONENTS

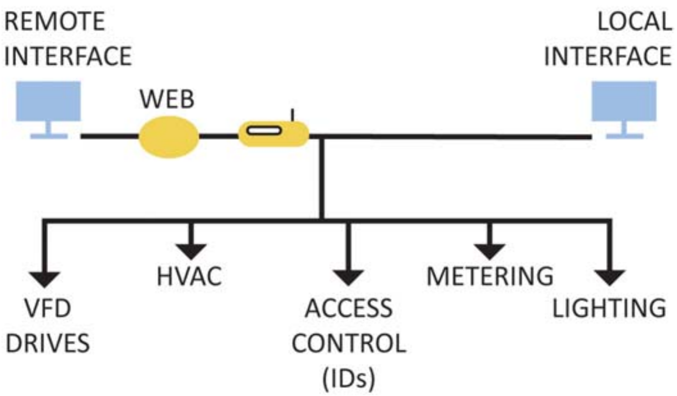


Figure 23 08-21

CONSIDERATIONS FOR HVAC EQUIPMENT SELECTION:

Factors for selecting certain HVAC systems are numerous.

- **Energy sources available**
  - Gas can be used in a boiler or gas heat section of an AHU to provide heat.
  - Electricity can be used efficiently in a heat pump or VRF system for heating and cooling.
  - Geothermal systems operated by electricity can be used with a heat pump to provide heated/chilled water or in a packaged heat pump to provide heated/cooled air.
- **Interior HVAC equipment space available**
  - Existing ductwork, hydronic piping, and mechanical rooms can often be reused.
  - Spaces that require the mechanical equipment to be hidden require a different design than spaces where ductwork and other equipment can be exposed.
- **Exterior HVAC equipment space available**
  - Exterior equipment can be installed to conserve space inside the building but is also required for air-cooled cooling systems.
    - Air conditioners work by moving heat from the conditioned space to the exterior which requires exterior equipment.
    - Geothermal heat pumps transfer heat from the space to or from the earth. Underground piping is required, but is not visible beyond man-hole covers.
  - Existing rooftop equipment or rooftop mechanical penthouse spaces can often be reused by new equipment.
  - Pad-mounted equipment is an option if no equipment is allowed on the roof.
    - Can be concealed in walls, fencing or landscaping but the top must remain open.
  - A geothermal bore field could be used if there can be no exterior equipment at all.

- **Historic Preservation Effects**
  - HVAC equipment selection can have a very large effect on historic properties.
  - Placement of exterior units must be carefully considered to avoid detracting from the character of the historic property. See Historic Preservation Effects under Forced Air Systems, Fan Coils and Ductless Split Systems.
  - Interior HVAC equipment selection can be minimized with systems that use piped fluids rather than air ducts that require more interior volume.

Maps produced by NREL for the US DOE

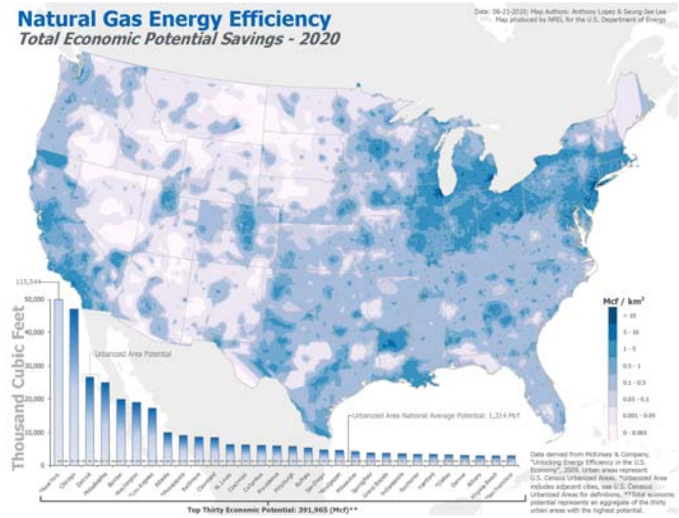


Figure 23 08-22

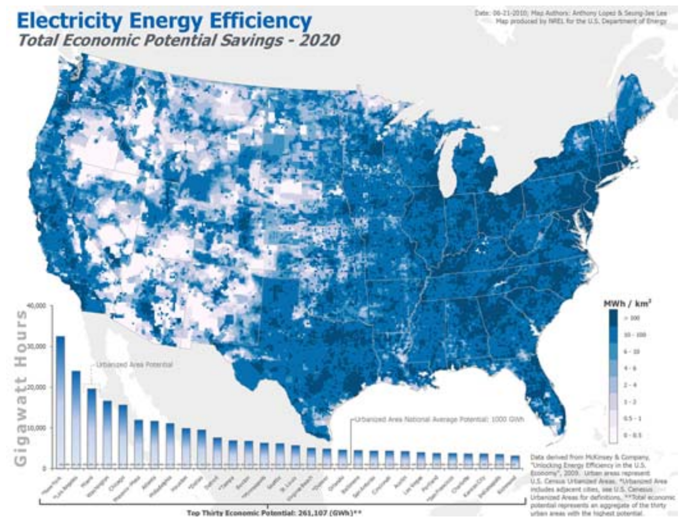


Figure 23 08-23

See Appendix G for larger versions of both maps

CONSIDERATIONS FOR HVAC EQUIPMENT SELECTION continued:

- **Energy Efficiency Potential:**
  - HVAC equipment is a very large factor in a building's energy usage. More efficient equipment is almost always more expensive. Building insulation and infiltration also factor into the HVAC energy usage.
    - Examples of energy efficient equipment include:
      - Fan coils with efficient boilers and chillers
      - VRF systems
      - Ductless split systems
      - Packaged units with 80%+ gas heat efficiencies and EER greater than ASHRAE 90.1 requirements.
      - Packaged unit heat pumps with backup electric resistance heat
      - Geothermal heat pumps
    - Examples of non-energy efficient equipment include:
      - Equipment past its useful life expectancy with leaky housings and worn-out fan motor bearings.
      - Constant volume airflow systems which have to remain on at full speed during occupied hours (for ventilation) and provide over-heating and over-cooling to some areas while maintaining other areas at a comfortable level.
      - Electric resistance heating.

- **Cost Considerations:** The cost of upgrading or installing new mechanical equipment is always an overriding factor.
  - It is often less expensive to demolish an old system and install a new one than to upgrade and refurbish the existing system, although the interior and exterior space available for new HVAC equipment will have to be taken into account.
  - In certain cases the historic preservation of the building would overrule the new HVAC equipment and the HVAC design would need to reuse and refurbish all or some of the existing equipment.

GEOTHERMAL RESOURCE OF THE UNITED STATES:
Locations of Identified Hydrothermal Sites and Favorability of Deep Enhanced Geothermal Systems (EGS), produced by NREL for the US DOE.

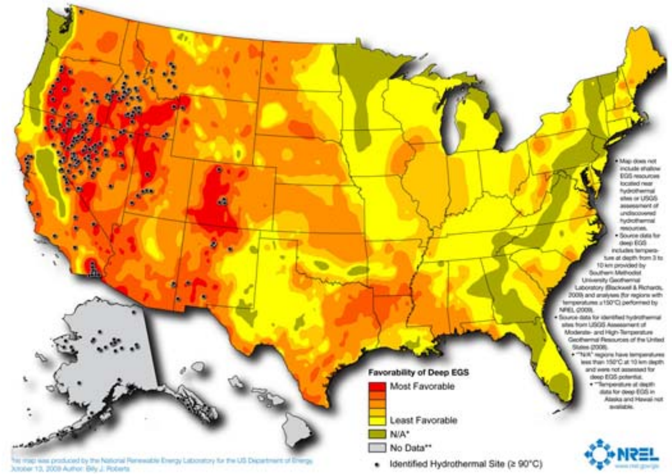
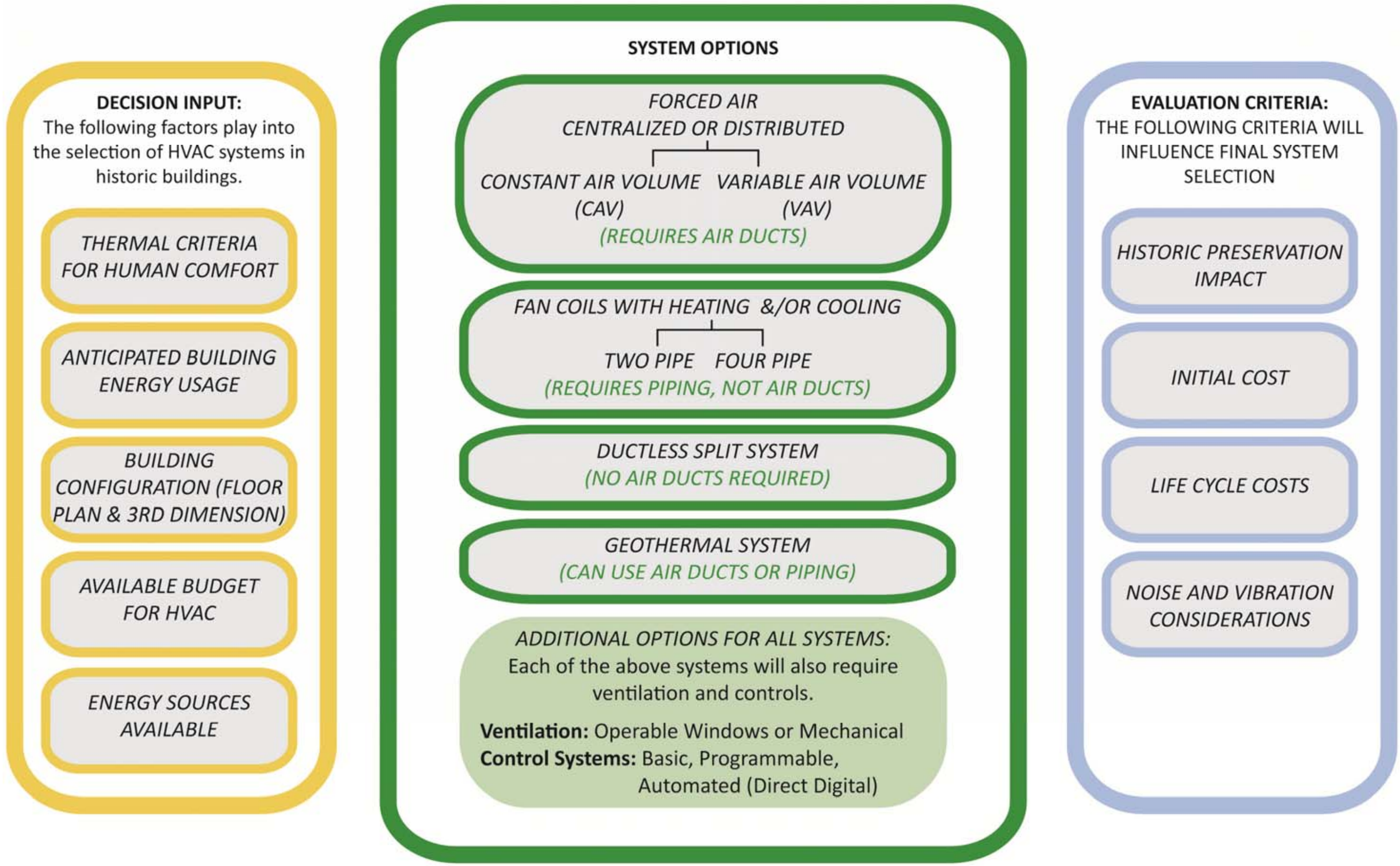


Figure 23 08-24
See Appendix G for larger versions of the map

HVAC systems can have a dramatic effect on the energy usage and, therefore, the energy efficiency of a building. When determining the right HVAC renovation project for a historic building consider the following:



GUIDELINE DESCRIPTION: Background information on HVAC nomenclature and zoning will be presented and discussed. Ductwork and piping, hot-water radiant coils, fan coils, indoor sections of split systems, VAV terminal units, mechanical room space and existing floor plan, and air distribution and equipment concealment will be evaluated. Selecting an HVAC system (see Guideline 23 08) narrows down the interior equipment options, but specific interior equipment must still be determined. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 23 08 Selecting HVAC Systems
- 23 12 HVAC Exterior Placement

GENERAL NOTES:

- **Secretary of the Interior Standards: Applicable for all systems listed under this Guideline**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic
- **Air volume heating/cooling is both sensible and latent.**
  - Cooling air is delivered around 55 deg F, and heating air is delivered at 90-95 deg F, so that the HVAC air is 20 deg F from the room temperature.
  - Latent cooling is the energy required to dehumidify the air before it can be cooled.
    - Warmer air can have more moisture, so that when it is cooled it also has to be dehumidified (producing condensation off the cooling coil).
    - Condensate should be piped to the building drain with an air gap.
  - Cooling airflow is typically 300-500 cfm (cubic feet/minute) per ton.
    - For example, 12 MBH (one ton) of cooling at 400 cfm requires a 10” duct.
- **Interior placement of HVAC equipment depends on the zoning requirements.**
  - When adjacent rooms need to separate zones (controlled by separate thermostats), the HVAC system needs to be able to deliver independent heating and cooling to the zones.
  - One AHU/ RTU to all rooms cannot deliver varying zones without additional equipment.
  - Examples of zoning equipment: Separate ducts to each zone from a VAV reheat system. Fan coils in each zone with heating/chilled water piping and valves

Common Terms used for Heating and Cooling:

BTU/hr *– measurement of heating and cooling*
1 BTU is the energy required to heat 1 pound of water 1 degree.

MBH *– 1,000 BTU/hr, 12 MBH = 1 ton*

Ton *– measurement for cooling only (1 ton of cooling is 12,000 BTU/hr or 12 MBH).*

Kilowatts *(kW) converted into BTU/hr and tons*
1 kW = 3412 BTU/hr = 3.4 MBH
3.5 kW of electrical energy requires 1 ton of cooling

delta T *– difference in temperature. In hydronic (heating/cooling water) calculations, typically 10-20 deg F.*

GPM *– gallons per minute, the flowrate of heating/cooling water.*

Hydronic energy is calculated by:
BTU/hr = delta T x GPM x 60 min/hr x 8.33 lb/gal, simplified to BTU/hr = delta T x GPM x 500.
(Therefore, 12 MBH, 1 ton, with delta T of 15 degF requires 1.6 GPM, which can flow through ¾” supply and return piping compared to a 10 inch duct for the equivalent forced airflow).

CONSIDERATIONS FOR DUCTWORK AND PIPING:

- **Approach:**
  - Nearly all HVAC systems use interior ductwork, water piping, and/or refrigerant piping.
  - Ductwork can be installed in existing building cavities: ceilings, floors, soffits, and in renovated spaces designed around ductwork, like new dropped ceilings and soffits.
    - Both round and rectangular ductwork are available. Rectangular ductwork can move more air through tight and narrow spaces, but round ductwork is less expensive.
  - Hydronic (heating/cooling water) and refrigerant piping requires less room than ductwork to deliver equivalent cooling/heating but also requires terminal units to transfer the cooling/heating to the air, like radiators, baseboards, and fan coils.
    - Supply and return piping have to be installed. A four-pipe system can provide heating and cooling to different zones at the same time, and a two-pipe system can be in heating or cooling mode at one time.

- **Historic Preservation Effects:**
  - Existing ductwork and piping can often be reused if it is still in good condition.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Poorly insulated ductwork and piping causes a loss of energy efficiency. Ductwork and piping should be insulated per the relevant codes (examples: UFC, UMC, UPC).
  - Leaky ductwork loses energy efficiency if tempered air is being supplied to areas that do not require HVAC. For example, leaky supply ducts in ceiling spaces waste energy.

- **Cost Considerations:**
  - Sealing leaky ductwork or insulating piping or ductwork has a cost, but gaining access to the ductwork or piping and then patching the wall/ceiling can also be a largely expensive alternative.
    - New ductwork and piping should always be thoroughly sealed, tested, and insulated before covering it up in wall and ceiling cavities.

Figure 23 11-1
New drop ceiling allows ductwork to be in the ceiling plenum. Notice that the drop ceiling stops several feet before the windows so that the historic windows are not covered or damaged.
Coronado School, Albuquerque, NM

Figure 23 11-2
Exposed ductwork before the ceiling is installed. While painting and leaving ductwork exposed is very common, it is rarely an acceptable solution in a historic renovation project.

CONSIDERATIONS FOR RADIANT HEATING:

- **Approach:**
  - Radiant heating is more effective than radiant cooling. Radiant heating from equipment placed low in the room provides a comfortable space temperature, while radiant cooling from the same equipment does not address the fact that heat rises and the cooling load is at the top of the room, and it leads to uneven temperatures in the room. Radiant heating is commonly used with fin tube radiators and radiant floors.
    - Chilled beams placed in the ceiling are a modern take on radiant cooling, and are much more effective because they provide more comfortable and even temperatures. Chilled beams work by bringing in warm air above a cooling coil then allowing the cooled air to exit below the coil.
    - Fin tube radiators consist of a main serpentine tube with fins attached to the tube to increase the surface area of heated metal exposed to the air.
      - Fin tube radiators require hydronic piping from the boiler system to the radiators, and also take up a block of space in the room.
      - Radiators can be furred in to be less visible, but some clearances to combustible construction materials are still required.
    - Baseboard heating is a fin tube radiator in a short form factor, commonly installed up against exterior walls.
      - Occupies long sections of the wall but is effective at keeping the room comfortable when the equipment is placed properly.
      - Furniture has to be kept away from baseboard heating.
  - Historic buildings with fin tube or baseboard radiators can potentially re-use the radiators and piping during an HVAC upgrade.

- **Historic Preservation Effects:**
  - Existing radiant heaters can be an integral part of the historic building. In some cases, removing them would take away from the building's character.
  - If the radiant heaters are still in good condition, and it is desired to conceal them, the units can be furred in with sufficient clearances and appropriate grills or other perforated covers.

Figure 23 11-3 Radiators are typically located low in the room, like under a window.

Figure 23 11-4 Contemporary chilled beam

CONSIDERATIONS FOR RADIANT HEATING continued:

- **Energy Efficiency Potential:**
  - The energy efficiency of a radiant heating system depends on all the components including the boiler(s), piping, and radiant heaters. A well designed system with efficient boiler(s) and good piping insulation can be energy efficient.
    - Boilers can range from 80% up to 95% efficient.
    - Radiant heating does not use energy to power fans but does require heating and pumping energy.
      - Fan energy is a large factor in most non-radiant HVAC systems.
      - Radiant heating alone cannot provide ventilation so operable windows or a dedicated ventilation unit are required.

- **Cost Considerations:**
  - Radiant heating systems are not as common as they once were because most buildings now require heating and cooling. New or upgraded HVAC systems can use radiant heating with 'perimeter zoning' to heat interior space next to an exterior wall but a separate cooling system would still be required.
  - If a historic building has existing radiant heating, then the cost of reusing an existing radiant heating system depends on the condition of all the components and piping. If the heaters and piping are in good condition but the boiler is beyond its estimated lifespan, it would likely be cost effective to install a new high efficiency boiler to reduce maintenance and energy usage.

Figure 23 11-5 Examples of different types of fin tube radiators

Figure 23 11-6 Radiator furred into the wall

Figure 23 11-7 Baseboard heater

CONSIDERATIONS FOR FAN COILS AND DUCTLESS SPLIT SYSTEMS:

- **Approach:**
  - Fan coils provide heating and/or cooling to specific zones. A fan coil contains a heating and/or cooling coil and a fan to circulate the air through the coil(s).
    - Take precautions to ensure low noise levels from the fan coils. Sufficient straight duct before and after fan coils and elbows in the ductwork reduce noise levels.
    - Fan coils come in many different configurations
      - Concealed: hidden in soffits, ceiling space, or furred in. Supply / return ductwork connect to the fan coil. The visible portion is a supply diffuser and return grille.
      - Exposed: visible to the room, either in horizontal or vertical configurations. Duct-less split systems have exposed interior fan coils, installed high on a wall.
  - Do not provide ventilation unless outside air is provided through a separate duct.
  - The cooling coils of fan coils collect condensate which is collected in a pan underneath the coil. The condensate can either be gravity drained or pumped to a place it can connect to a building drain with an air gap fitting.

- **Historic Preservation Effects:**
  - Fan coils, VRF systems, and ductless split systems can be well concealed.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Fan coils, VRF systems, and ductless split systems can have high energy efficiency. The biggest factor in the energy savings is the reduced fan power that is required to circulate air within a room compared to circulating air through long stretches of ductwork and through an air handling unit.
    - Hydronic fan coil efficiency depends on the boiler and chiller that provide the heating or cooling water. Equipment that exceeds the minimum ASHRAE 90.1 requirements will provide better energy efficiency.
    - VRF and ductless split systems typically have a higher EER commonly 16 or higher than RTUs which are typically around 11.

- **Cost Considerations:**
  - Costs vary widely with fan coils, VRF systems, and ductless split systems. Fan coils require other components like boilers, chillers, and piping. VRF and ductless split systems can be cost effective because of their low energy use but the installed cost will vary from building to building because of specific building conditions. A life cycle cost analysis can be calculated to determine which options are cost effective.

Figure 23 11-8 Installed VRF Fan Coil

Figure 23 11-9 Interior fan coil of a ductless split system

CONSIDERATIONS FOR VAV TERMINAL UNITS:

- **Approach: This Guideline talks about the VAV configurations and how they can fit in the interior**
  - VAV terminal units control the volume and heat of air from a central air handler to the rooms. Typically the main AHU high velocity supply ducts are installed above corridors, and small ducts tee off into the rooms, with the VAV terminal unit being installed directly above or near the room.
  - VAV supply ductwork takes up less ceiling space because the airflow can be at a higher velocity up until the VAV terminal. For example, 1,000 cfm would require a 14" diameter duct at low velocity in a constant volume system but only a 10" diameter duct in a VAV high velocity system.
  - Each VAV terminal is connected to a thermostat and is considered a 'zone'.
  - VAV terminal units typically have hydronic or electric reheat. Hydronic reheat requires piping from the boiler equipment to the VAV terminals. Electric reheat only requires wiring, although electric resistance heat is more energy-intensive than gas hot water heat.

- **Historic Preservation Effects:**
  - VAV terminal units can be well-concealed in interior cavities but do require ductwork and a source of airflow (AHU or RTU).
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Systems with VAV terminal units are more efficient than constant volume systems because the amount of heating and cooling to each zone varies with the load. When there is a smaller cooling or heating load, fan, heating and cooling energy are all reduced.

- **Cost Considerations:**
  - Systems with VAV terminal units are approximately 40% more expensive than constant volume systems but provide better efficiency and zoning.

Figure 23 11-10 VAV terminal with Hot Water Coil

Figure 23 11-11 VAV terminal with Reheat Coil

CONSIDERATIONS FOR MECHANICAL ROOMS AND EXISTING FLOOR PLANS:

- **Approach:**
  - Mechanical rooms are an effective way of concealing and isolating mechanical equipment. Existing buildings can have existing mechanical rooms, or new areas may be designated as mechanical rooms.
    - AHUs in mechanical rooms provide heating/cooling air through ductwork
    - An AHU is typically configured with a heating water coil and cooling water coils or refrigerated coil.
      - Heating water coils are fed with hot water from a boiler or another source (example: ground source heat pump)
      - Cooling water coils are fed with chilled water from a chiller or another source (example: ground source heat pump)
        - Water cooled chillers can be installed inside, but are connected to pumps and exterior cooling towers.
      - Water source (geothermal or boiler/cooling tower) heat pumps can be installed in mechanical rooms.
      - Boilers are typically installed in mechanical rooms, but require piping to the exterior for combustion air and exhaust.
  - Existing floor plans should be reviewed and coordinated with interior HVAC placement.
    - Hydronic piping can either be in a loop or 'out and back' configuration from the mechanical room to all the terminal units.
    - Ductwork can be designed in a variety of ways and must be coordinated with available interior space. One large supply duct or multiple smaller ducts can transfer the air to the rooms.
    - HVAC equipment requires space in a building but, with careful planning, its architectural impact can be lessened.

Figure 23 11-12 AHU in a mechanical room
AHUs are large pieces of equipment with required clearances. Careful planning is needed if existing mechanical rooms are to be used with newer (often larger) equipment.

Figure 23 11-13 2 AHU's for a hospital

CONSIDERATIONS FOR MECHANICAL ROOMS AND EXISTING FLOOR PLANS continued:

- **Historic Preservation Effects:**
  - Existing mechanical rooms can often be reused. The spaces should be checked for code compliance issues like fire walls and combustion air openings.
  - A building's floor plan is a determining factor in what HVAC system should be used to preserve the historic nature of the building.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - The energy efficiency of a system depends more on the specific HVAC equipment and system rather than the mechanical rooms themselves.
  - Examples of energy efficient equipment in mechanical rooms include: efficient condensing boilers, variable volume air handling units (AHUs), and efficient chillers with exterior cooling towers.

- **Cost Considerations:**
  - Reusing existing mechanical rooms, if available, is often the lowest-cost solution, although the rooms require sufficient access and a way to remove old equipment and bring in new equipment. Sometimes, additional funds are required to bring old mechanical rooms up to code.
  - Floor plans should be studied to assist in determining the best interior HVAC equipment to install, rather than selecting equipment and trying to make it fit the building.
  - Existing ductwork and piping should be evaluated for its condition and possible reuse.

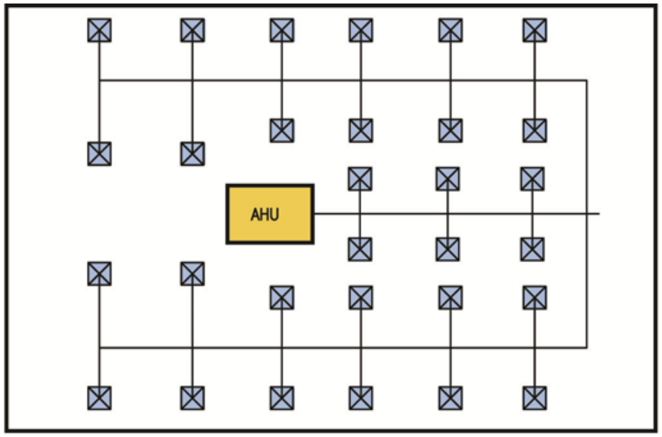


Figure 23 11-14 The AHU is housed in a mechanical room. Building configuration is critical in determining what space (if any) is available for mechanical room.

CONSIDERATIONS FOR AIR DISTRIBUTION AND EQUIPMENT CONCEALMENT:

- **Approach:**
  - Air distribution and equipment concealment can be accomplished a variety of ways.
    - Ductwork can be concealed in ceiling spaces, soffits, or underground
      - Underground duct connected to floor level registers can be installed to reduce or eliminate ductwork from the walls and ceilings.
      - Ductwork can be installed in basements or attic spaces.
      - Ceiling plenums or transfer grilles can be used to return air back to an air handler or fan coils while ductwork is used for the supply air. The path of the return air is not obvious and visible but is effective.
        - Wood or other flammable construction requires the return air to be ducted back to the HVAC equipment instead of returning via a ceiling plenum.

- **Historic Preservation Effects:**
  - Existing air distribution ductwork can often be reused if it's in good condition.
  - Concealed ductwork and equipment are a big factor in historic building renovations.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Ductwork is an important factor in a HVAC system's energy efficiency and should be well sealed, insulated, and sized correctly. Properly sized, sealed and insulated ductwork will improve HVAC energy efficiency. Ductwork that is too small requires more fan energy, and poorly insulated ductwork contributes to heat loss.

- **Cost Considerations:**
  - Costs for concealing ductwork and equipment are part of the general construction of a building renovation and depend highly on architectural design.
  - Round ductwork is less expensive than rectangular ductwork although rectangular ductwork can supply more air through tight spaces.

Figure 23 11-15 Ductwork concealed in a new dropped ceiling space, but detailed to respect the historic windows.
JW McCormick Place, Boston, MA

Figure 23 11-16 Insulated ductwork installed above new lay-in ceiling (ceiling tiles not installed yet)

GUIDELINE DESCRIPTION: Background information will be discussed about why exterior HVAC equipment is required, placement options, and the architectural options for hiding the exterior equipment. The Guideline will describe rooftop and pad-mounted (ground-level) equipment: packaged HVAC units, chillers and cooling towers, and split system condensing units. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 23 08 Selecting HVAC Systems

GENERAL NOTES:

- **Secretary of the Interior Standards: Applicable for all systems listed under this Guideline**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- HVAC requires exterior equipment in order to reject or absorb heat from the atmosphere or earth. An air conditioner works by removing heat from interior spaces and rejecting it outside to keep the interior space cool. A heat pump works the opposite way, absorbing heat from the exterior and rejecting the heat inside.
  - Ground source (geothermal) heat pumps reject and absorb heat into the earth rather than the atmosphere. Even though geothermal systems require exterior equipment, it is hidden underground.
- Exterior equipment is typically placed on a rooftop or at the ground level on a concrete housekeeping pad, depending on the space available. Rooftop equipment can be placed in a penthouse if no heat rejection is required.
- Air-cooled rooftop and pad-mounted equipment can be installed with walls, fences or landscaping that shield the equipment from view where the heat rejection fans can still discharge air upward. Manufacturer required clearances need to be maintained.

Figure 23 12-1 Rooftop Screen Wall, screens can make the installation of both roof mounted and pad mounted HVAC equipment more acceptable for historic buildings.

CONSIDERATIONS FOR PACKAGED HVAC UNITS:

- **Approach:**
  - Packaged units come in multiple configurations.
    - Packaged units can be installed on a roof curb with heating/cooling air typically supplied and returned vertically to the building
    - Packaged units can also be installed on a ground-level concrete pad with air ducted horizontally into the building.
  - Packaged units are typically air cooled and reject heat into the atmosphere.
    - Water cooled (geothermal) heat pumps are different and reject heat to water instead of air.
  - Packaged heat pumps can be cooled by air or water, and provide both heating and cooling from electrical power. The cooling operates like a typical air conditioner, and the cycle is reversed for the heating cycle.
    - Heat pumps are less efficient at cooler temperatures and can be ineffective below about 40 deg F. For cold climates, backup electric resistance heat is required.
  - Packaged units can use a variety of energy sources
    - Hydronic cooling and/or heating coils can be used if chillers and/or boilers are installed.
    - Electric (DX refrigeration cycle) cooling is often used.
    - Heat can also come from gas or electricity.
      - Gas heat is often used when propane or natural gas is available
      - Electricity can provide heat via a heat pump or electric resistance heater.
        - Resistance heat is energy intensive and should only be used where gas is unavailable, or electricity from renewable sources is abundant and inexpensive.
  - Cooling coils, including those in packaged HVAC units, produce condensate which should be piped to a drain with an air gap where possible. Condensate should not be drained onto a roof or cause a freeze and slip potential on a sidewalk.
  - Packaged HVAC units produce noise from fans and other components and should be located in areas where they will not bother occupants.

Figure 23 12-2 Packaged Roof Top Unit (RTU) VRF Rooftop Units installed within a screen wall. This is a bird screen to protect the equipment.

Figure 23 12-3 Packaged Rooftop Unit with Economizer

CONSIDERATIONS FOR PACKAGED HVAC UNITS continued:

- **Historic Preservation Effects:**
  - Packaged HVAC units can be a good fit in a historic building if designated roof or pad-mounted space is available because they are relatively easy to install and maintain and all the components are contained in one area.
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Packaged HVAC units can be an integral part of an energy efficient system. Packaged units are available in a range of efficiencies and more efficient units are typically more expensive.
  - Economizers improve the energy efficiency of packaged equipment. Economizers bring in more outside air when the air temperature is favorable, for instance, when it is cool outside and the building requires cooling.
  - Compare the energy efficiency (EER and/or COP) of packaged HVAC equipment to the minimum requirement in ASHRAE 90.1 to determine the relative efficiency.

- **Cost Considerations:**
  - If the existing building has an existing packaged HVAC unit that is being replaced and serving existing ductwork, only the cost for the packaged unit and installation need to be considered. If the ductwork is new or redesigned, there will be significant added cost.
  - Packaged HVAC Rooftop Units are typically about $1,600/ton for constant volume and $1,900/ton for variable air volume units.

Figure 23 12-4 Packaged Rooftop Unit with Gas Heat

Figure 23 12-5 Variable Air Volume (VAV) Packaged RTU (gas and condensate piping are visible)

CONSIDERATIONS FOR CHILLERS AND COOLING TOWERS:

- **Approach:**
  - Chillers provide chilled water to cooling coils. Cooling coils can be installed in a variety of HVAC equipment like AHUs, RTUs, and fan coils.
  - Chillers can be air cooled or water cooled.
    - Air cooled chillers are exterior equipment that reject heat to the outside air and cannot be completely closed in
    - Water cooled chillers are more efficient and are typically located indoors but require additional exterior connected equipment. Exterior cooling towers, piping, and pumps are required for water cooled chillers.
      - Glycol is added to the chilled water in cold climates to reduce freezing potential.
  - Cooling towers and chillers are noisy like other HVAC equipment and the distance to building occupants should be kept in mind during the design.

Figure 23 12-6 Chillers

- **Historic Preservation Effects:**
  - See comments on interior spaces in Historic Preservation Effects for **FORCED AIR SYSTEMS** and **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Water cooled chillers are more efficient than air cooled chillers but require more associated equipment like cooling towers.
  - As with other HVAC equipment, more efficient products are more expensive but can payback in a reasonable timeframe.

Figure 23 12-7 Cooling Tower

- **Cost Considerations:**
  - An HVAC system with chillers and cooling towers needs to be associated with a complete system containing the necessary piping, heating and air distribution system.

CONSIDERATIONS FOR SPLIT SYSTEM CONDENSING UNITS:

- **Approach:**
  - Condensing units are half of a split system and reject or absorb heat from refrigerant to the outside air. They are installed outside and cannot be closed in, and they come in various sizes depending on the cooling requirements.
    - Split systems are typically cooling only or heating/cooling combination.
      - The heating/cooling versions are heat pumps.
      - The interior fan coil is the other half of the split system
  - A condensing unit fan moves air through the coil which can have noise levels that should be considered.
  - Manufacturers limit the distance and elevation difference between the outdoor condensing unit and interior fan coil of a split system.
  - Can be installed on roofs or concrete pads on the ground, and have two pipes for refrigerant to flow to and return from the interior fan coil.

- **Historic Preservation Effects:**
  - The condensing unit also requires an interior fan coil in addition to exterior space.
  - See comments on exterior installations in Historic Preservation Effects for **FAN COILS AND DUCTLESS SPLIT SYSTEMS.**

- **Energy Efficiency Potential:**
  - Split systems are energy efficient because the fan energy is less than alternatives (like packaged RTUs). The heating/cooling energy is transferred through the pumped refrigerant piped to the interior coil, rather than the larger fan of a packaged unit moving airflow through ductwork to transfer the heating/cooling.

- **Cost Considerations:**
  - Split systems can be relatively inexpensive to install if the exterior equipment and piping location has good access, and the refrigerant piping distance is short.

Figure 23 12-8 Exterior condensing unit for a ductless split system (fan visible)

Figure 23 12-9 Roof Mounted Condensing Unit for ductless split system

GUIDELINE DESCRIPTION: This Guideline will review the different types of ground loop systems (ground source or geothermal heat pump systems) and how they can be applied to historic structures. It will discuss the basic principles of how each system works and how it can be installed in a historic structure. Use in conjunction with Guideline 23 08 Selecting HVAC systems. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meets UFC requirements.

Terminology:

Closed Loop Control: A closed loop control directly senses the controlled variable and uses that signal to adjust the controlled device.

Open Loop Control: An open loop control does not have direct feedback from the control variable to the controller.

RELATED GUIDELINES:

- 22 33 Hot Water Energy Conservation
- 23 08 Selecting HVAC Systems
- 23 11 HVAC Interior Placement

GENERAL NOTES:

- Geothermal heat pump systems use the ground as a stable-temperature 'heat sink' that can absorb or reject heat to/from a circulating fluid, such as water.
- Geothermal heat pump systems come in different configurations, each with its own strength and weakness.
- There are two primary types of Geothermal systems that will be discussed below:
    - o **Closed Loop**
    - o **Open Loop**

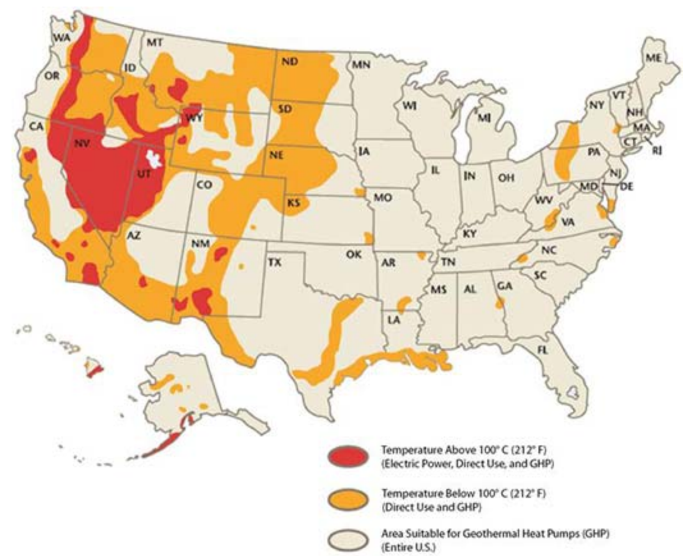


Figure 23 21-1 Map of ideal geothermal heat pump usage.
See appendix N for larger version of map.

CONSIDERATIONS FOR USING GEOTHERMAL HEAT PUMP SYSTEMS:

- **Approach:** (Energy.gov, "Department of Energy," 2014)
  - Use the ground as a stable-temperature 'heat sink'.
    - The earth, at around 55-60 deg F, can absorb heat from fluid above that temperature and transfer heat into fluid below that temperature.
    - Geothermal heat pump systems boost or lower the temperature of the fluid and provide heating/cooling to a building.
      - These systems use a water/glycol mix when chilled water is expected to go below freezing.
  - Use either a vertical bore field with wells, or horizontal trenches for piping.
    - The bore field or trenching size requirements vary with the size of the geothermal system, determined by the energy model for the heating/cooling required in the building and the soil test data.
    - If more land area is available and the soil temperature near the ground level is stable enough, then a horizontal bore field could be more cost effective.
    - If the bore field needs to take up less land, a vertical arrangement can be used.
      - Bore field depth varies by geographic location.
    - A bore field can be installed under a parking lot, accessed by simple manholes.
    - Trenches can also be installed under a parking lot, but are more difficult to access.
  - Ground Testing to provide the designer with accurate information on the Thermal conductivity.
    - Tests are generally conducted by drilling a bore hole and adding a loop.
    - Test bore data and drilling conditions on site.
    - From this, the conductivity and diffusivity can be calculated to determine which Geothermal Heat pump system is suitable for the site.

- **Loop Type:**
  - Closed Loop:
    - "Closed-loop" is used to describe a geothermal heat pump system that uses a continuous loop of special buried plastic pipe as a heat exchanger.

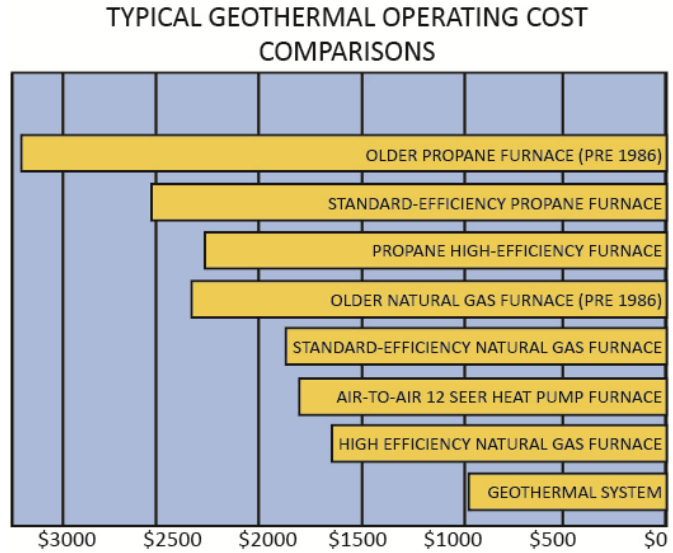


Chart 23 21-1

Figure 23 21-2 Closed Loop System

CONSIDERATIONS FOR USING GEOTHERMAL HEAT PUMP SYSTEMS continued:

- **Loop Type continued:**
  - Closed Loop continued:
    - Closed loop systems have a dedicated fluid loop that is circulated through the ground or pond in order to exchange energy.
    - The ground/pond water and loop water do not mix, recirculating its heat transferring solution in a pressurized pipe.
    - Pipe is laid underground and heat-absorbing carrier fluid, usually with anti-freeze properties, is pumped through.
    - Pros:
      - Control over water / brine quality.
      - No scaling or build-up concern.
      - Less maintenance.
      - Zero water usage from well.
      - Zero Energy Consumption from well pump.
    - Cons:
      - Typically higher initial install costs.
      - Requires yard space.
      - Lower entering water temperatures (heating).
    - Maintenance Considerations:
      - Corrosive to the copper tubing.
      - Direct exchange system requires larger compressor.
      - Additional irrigation to keep the soil moist.
  - Open Loop:
    - An Open Loop System is a geothermal heat pump system that uses groundwater from a conventional well as a heat source in winter and a heat sink in summer. The groundwater is pumped through the heat pump where heat is extracted (in winter) or rejected (in summer), and then the water is disposed of in an appropriate manner.
      - The piping can run in a parallel or series configuration (two-pipe or four-pipe).

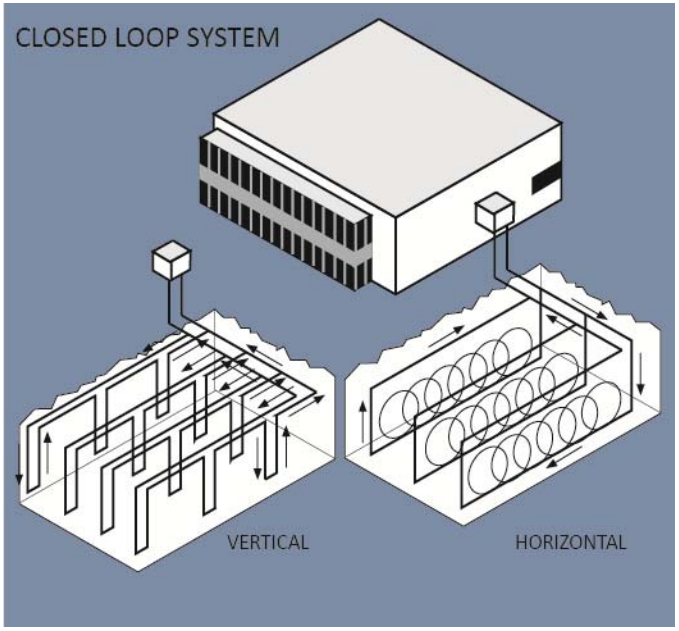


Figure 23 21-3 Closed Loop System

CONSIDERATIONS FOR USING GEOTHERMAL HEAT PUMP SYSTEMS continued:

- **Loop Type continued:**
  - Open Loop continued:
    - Pros:
      - Less expensive install costs (in most cases).
      - Consistent entering water temperature.
      - Slightly more capacity in late winter.
    - Cons:
      - Increased well pump usage.
      - Must have adequate supply of relatively clean water and regulations regarding groundwater discharge are met.
      - Water quality concerns.
      - Additional water control valve required.
      - Discharge water location / design required.
    - Maintenance Considerations:
      - Mineral deposits can build up inside the heat pump's heat exchanger.
      - Impurities, particularly iron, can eventually clog a return well.
      - If the water has high iron content, one should be sure that the discharge water is not aerated before it is injected into a return well.
      - Opt against using water from a spring, pond, lake, or river as a source for the heat pump system, unless it is proven to be free of excessive particles and organic matter. They could clog a heat pump system.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes

- **Historic Preservation Effects:**
  - Geothermal equipment can preserve the exterior look of a historic building because the heat transfer is to/from the earth rather than to/from the atmosphere around a building.

Figure 23 21-4 Open Loop System

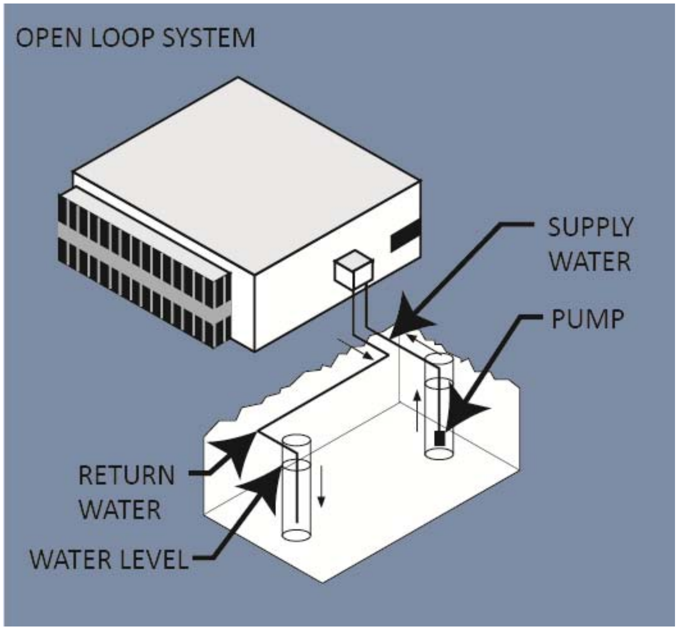


Figure 23 21-5 Open Loop System

CONSIDERATIONS FOR USING GEOTHERMAL HEAT PUMP SYSTEMS continued:

- **Historic Preservation Effects continued:**
  - These are very quiet systems with minimal vibrations. Therefore, they can be a good option for buildings in which there are noise related concerns.
  - Since Geothermal HVAC systems can be used with AHUs, or piped fluids, the interior impacts are similar to those noted with centralized air systems.

- **Energy Savings Potential:**
  - Geothermal heat pumps are typically 30% more efficient than air-source heat pumps and geothermal heat pump systems can have low energy usage similar to VRF systems.
  - The geothermal aspect of the system is only part of the equation. The efficiencies of the heat pump and water pumps and heating/cooling equipment like air handlers and fan coils are as important as the geothermal field.

- **Cost Considerations:**
  - Geothermal systems are at least 30% more expensive than conventional air-cooled systems, but because of their greater efficiency they can have long-term cost savings. A life cycle cost analysis should be performed to compare the options since the cost of geothermal systems vary greatly based on geographic location.

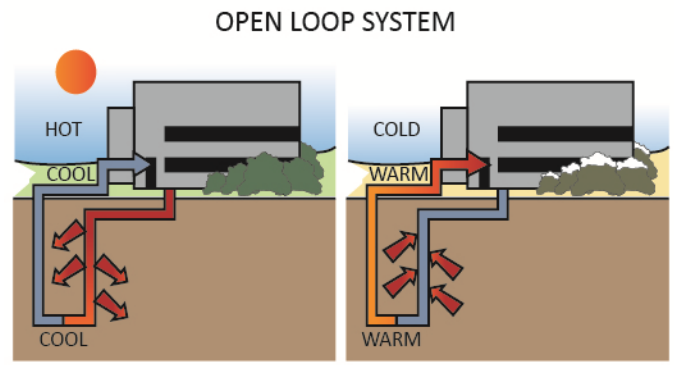


Figure 23 21-6 Summer and Winter diagram of open loop system

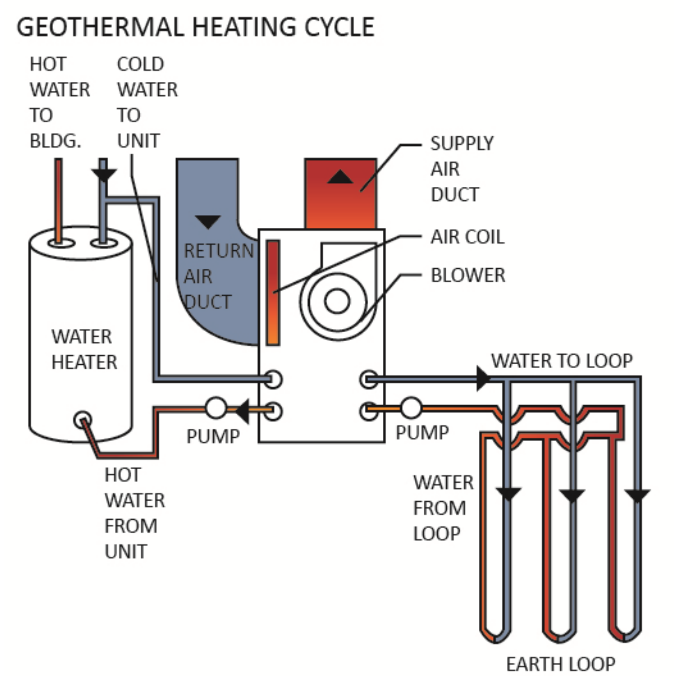


Figure 23 21-7 Diagram Geothermal Heating cycle

GUIDELINE DESCRIPTION: This Guideline will provide an in-depth review of centralized air and distributed air systems, and will explain how these systems can be applied to historic buildings. It will discuss the basic principles of how each system works, and will discuss methods for installing these systems in a historic building without altering the historic character defining features. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 23 08 Selecting HVAC Systems
- 23 11 HVAC Interior Placement
- 23 12 HVAC Exterior Placement

GENERAL NOTES:

- Ventilation is the addition of clean, often filtered, air to a building space to control airborne contaminates and to provide the required volume of fresh air for human occupancy.
  - The ventilation air may or may not be thermally conditioned depending on the type of building space being supplied.
  - The volume of ventilation air required for human occupied spaces is detailed in ASHRAE Standard 62.1, "Ventilation for Acceptable Indoor Air Quality," Table 6.1: Minimum Ventilation Rates in the Breathing Zone.
- Most buildings have areas of different occupancy that require varying amounts of heat removal or addition at different times throughout the day, due to solar loading.
  - Each of these areas or building exposures would potentially need different volumes of supply air, as well as different amounts of energy removal or addition to maintain the temperature set-points.

Terminology:

Chiller: *A machine that removes heat from a heat transfer liquid using a refrigeration cycle.*

Constant Air Volume (CAV): *Use of constant air flow volume to a zone to thermally condition the zone.*

Variable Air Volume (VAV): *Use of a variable air flow volume to a zone to thermally condition the zone.*

Central Fan System: *A mechanical indirect system of heating, ventilating, or air-conditioning. Air is treated or handled by equipment that is usually located outside the rooms served at a control location and conveyed to and from the rooms via a fan and system of distributing ducts.*

Centralized System: *A majority of the mechanical systems (chillers, pumps, air handlers, etc.) are located in one mechanical space.*

Packaged Rooftop Unit: *A complete air handler system, typically with multiple cooling and heating stages.*

CONSIDERATIONS FOR USING A CENTRALIZED AIR SYSTEM:

- **Approach:** (GreenBuildingAdvisor.com 2013)
  - **Centralized HVAC systems** would have a majority of the mechanical systems (chillers, pumps, air handlers, etc.) in one mechanical space and the conditioned air, water, or steam would be piped or ducted to the zone where a local distribution or control system would be located.
    - Cooling towers and chillers are noisy like other HVAC equipment and the distance to building occupants should be kept in mind during the design.
  - **Chillers:**
    - A chiller is a machine that removes heat from a heat transfer fluid using a refrigeration cycle (vapor compression cycle or absorption refrigeration cycle).
      - Vapor compression cycles are of the most common methods used for conditioning air in the building.
      - Vapor compression cycles use a circulating media to absorb heat from another media such as water or air.
      - Absorption chillers use a heat source to provide energy to drive the cooling system.
      - The main difference between the two types of systems is the way the refrigerant is changed from a gas state to a liquid state.
      - Absorption chillers change the refrigerant gas back into a liquid using a method that requires heat, not mechanical compression and heat rejection.
      - Chillers provide chilled water to cooling coils. Cooling coils can be installed in a variety of HVAC equipment like AHUs, RTUs, and fan coils.
      - Chillers can be air cooled or water cooled.
      - Air cooled chillers are exterior equipment that reject heat to the outside air and cannot be completely closed in.
      - Water cooled chillers are more efficient and are typically located indoors, but require additional exterior connected equipment. Exterior cooling towers, piping, and pumps are required for water cooled chillers.
      - Glycol is added to the chilled water in cold climates to reduce freezing potential.

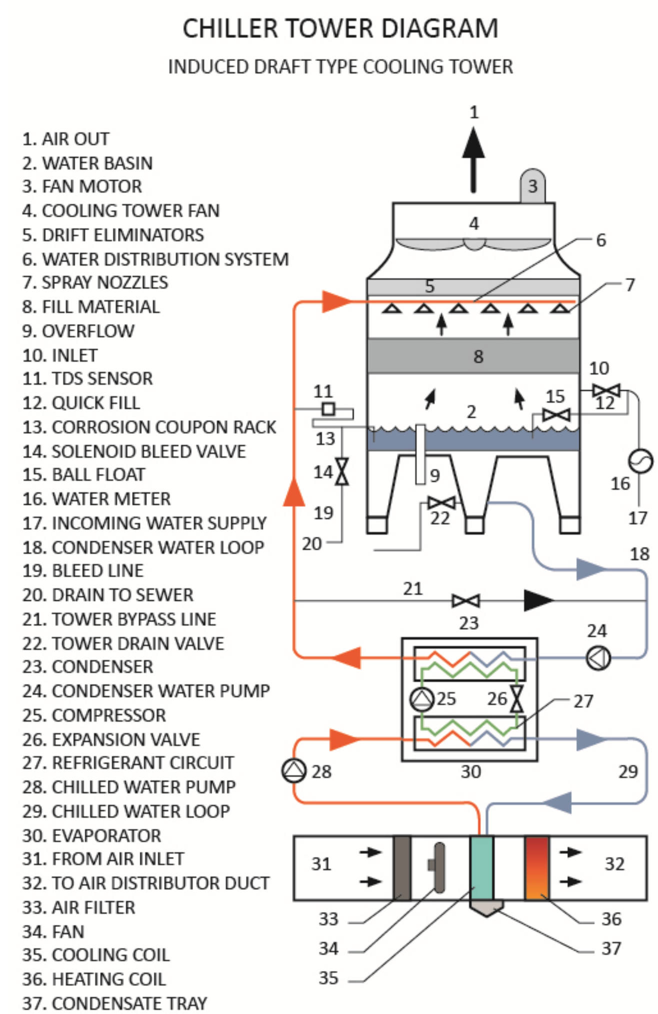
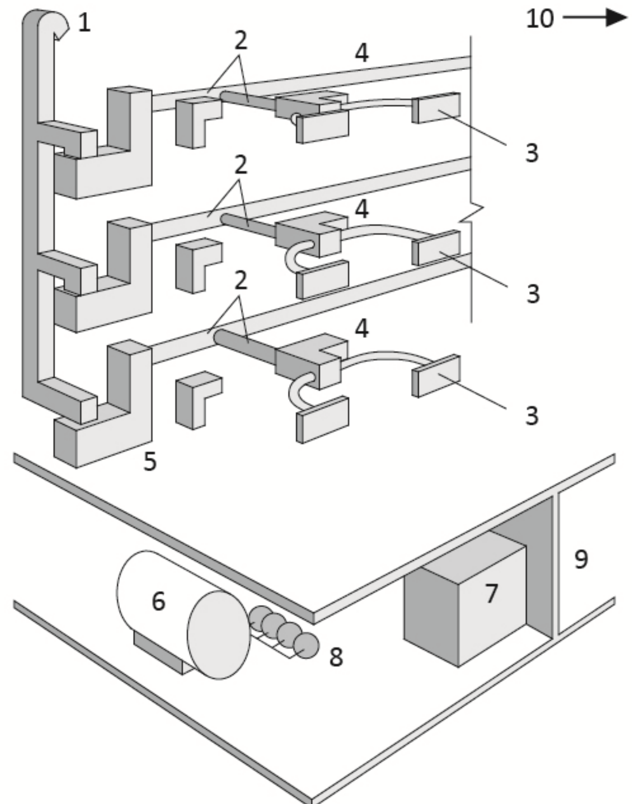


Figure 23 22-1

CONSIDERATIONS FOR USING A CENTRALIZED AIR SYSTEM continued:

- **Approach continued:**
  - **Distributed HVAC systems** may have some components in one central or general location. Then, at the control zone, additional equipment would be located to provide the actual tempering of the supply air.
    - Air-Conditioning (Heating and Cooling of Air): In an occupied building space, the air temperature is sensed by a thermostat, and depending upon the control sequence, the control system will maintain the space air temperature by either adding heat or raising and lowering the supply air temperature and/or air volume.
    - For cooling, the heat energy that is removed from the occupied space comes from the equipment, lighting, occupants, solar load, and shell gain.
    - The removal of this excess heat energy is performed by either the use of cool supply air or chilled water and supply air in a hydronic cooling system such as a radiant panel, sail, or chilled beam.
    - The temperature of the supply air and the volume of the cool supply air is often varied based on the amount of heat energy that needs to be removed to maintain the desired space temperature.
    - For heating in an air only system, the amount of heat energy that is lost through the building shell is offset by increasing the volume of warm supply air, increasing the temperature of the supply air, or increasing both the volume and temperature.
    - For heating with hot water only, the amount of heat energy that is lost through the building shell is offset by a radiant baseboard heater, radiant panel or sail, or active chilled beam.
    - When using hot water as the primary source of heating in an occupied space, ventilation air will still be supplied to maintain the indoor air quality needed for human occupancy, or fir the control of contaminates.
    - Ventilation is the addition of clean, often filtered air into a building space to control airborne contaminates and to provide the required volume of fresh air for human occupancy.
    - The ventilation air may or may not be thermally conditioned depending on the type of building space being supplied.

CHILLED WATER CENTRAL AIR CONDITIONING



1. OUTSIDE AIR INTAKE
2. DUCTS
3. DIFFUSER
4. TERMINAL UNIT
5. AIR HANDLER
6. BOILER
7. CHILLER
8. PUMPS FOR CHILLED WATER, HOT WATER AND COOLING TOWER.
9. ENERGY MANAGEMENT SYSTEM
10. COOLING TOWER (NOT SHOWN)

Figure 23 22-2

CONSIDERATIONS FOR USING A CENTRALIZED AIR SYSTEM continued:

- **Approach continued:**
    - The volume of ventilation air required for human occupied space will still be supplied to maintain the indoor air quality needed for human occupancy or for the control of contaminates.
        - An example of a distributed system would be a split refrigeration system. The compressor and condenser are located some distance away from the evaporator and fan.
        - Constant volume RTUs/AHUs are at a ratio of one per zone.
        - Variable speed RTUs/AHUs with variable volume terminals can have more zones.

- **Applicable Secretary of the Interior Standards:**
    - 2: Historic Character Preservation
    - 5: Distinctive Qualities Preservation
    - 6: Repair of Deteriorated Historic Features

- **Historic Preservation Effects:**
    - Existing ductwork in buildings may be reused to reduce the amount of demolition required.
        - Duct sizes may not be the optimum dimensions. More often, the location where the original ductwork ran may be appropriate for new ductwork.
    - Ducts can be located in basements and existing chases to reach upper floors. When there is no basement or chases connecting upper floors, new furred out areas must be created to locate horizontal ducts. Some alternatives include furring down a portion of the ceiling, or a portion of a hallway.
    - Vertical chases can be furred out in inconspicuous corners of rooms, or in former closets or other utility spaces.
    - Roof top units (RTUs) are not often recommended by CRMs/SHPOs on a sloped roof unless they are on a minor elevation of the building, not visible from a major elevation.
        - Buildings with sloped roofs often have attic spaces. If proper ventilation can be provided to the attic, AHUs can be located there.

Figure 23 22-3 Glycol feeder tank

Figure 23 22-4 Central Air System

CONSIDERATIONS FOR USING A CENTRALIZED AIR SYSTEM continued:

- **Historic Preservation Effects continued:**
  - Roof top units (RTUs) may be appropriate on flat roofs if there is a surrounding parapet tall enough to hide them from any major view of the building.
  - Ground mounted units can be hidden from view with landscaping or an appropriately designed fence.
    - The fence/landscaping must allow for air intake and heat disbursal from the unit.
    - Ground mounted units need to be very close to the building to avoid a loss of efficiency in delivering the conditioned air.
  - Fresh air intakes can be located where historic attic vents were located or where under-floor vent openings existed.
  - When historic buildings receive new heating systems, some CRMs/SHPOs prefer that historic heating fixtures (fireplaces, radiators, etc.) remain to exhibit the way the room appeared.

- **Energy Savings Potential:**
  - Energy Requirements:
    - AHUs require electricity for fans, dampers, and controls.
    - Cooling provided by chilled water or DX cooling (direct expansion cycle).
      - Chilled water can be provided from a central plant or can be produced at a specific building via an air-cooled chiller or cooling tower/chiller combination.
      - DX cooling uses the refrigeration cycle to cool the air.
      - DX cooling can be built into a 'packaged unit' or can be provided by a separate exterior condensing unit and evaporator inside the AHU.
  - Well-designed forced-air systems, installed properly and using efficient components, can be energy efficient.
  - Electric resistance heat should be used a minimal amount to increase the energy efficiency.
  - Water cooled chillers are more efficient than air cooled chillers but require more associated equipment, like cooling towers.

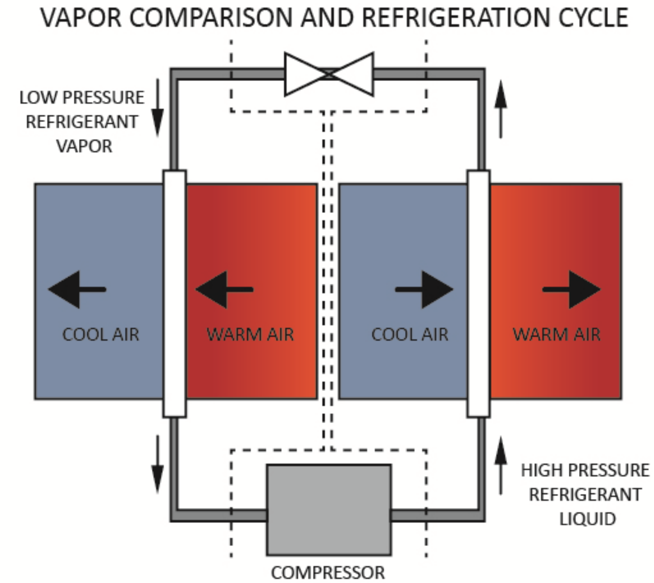


Figure 23 22-5

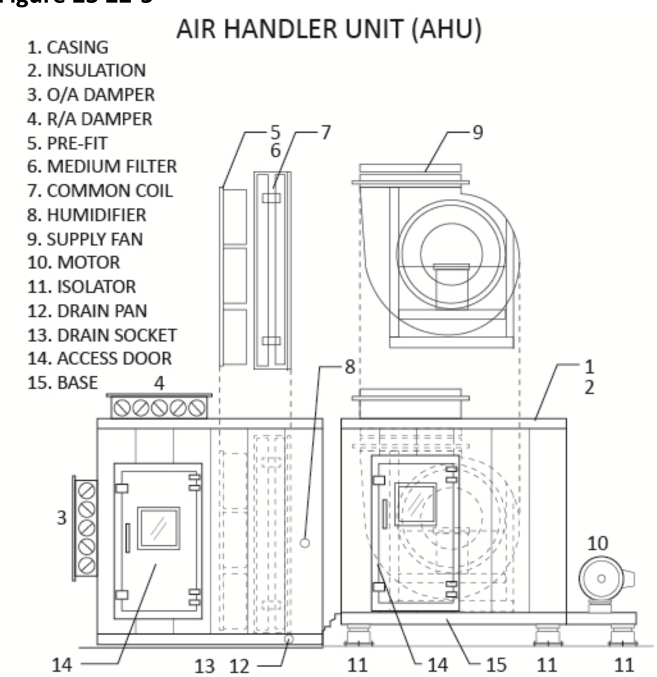


Figure 23 22-6

CONSIDERATIONS FOR USING A CENTRALIZED AIR SYSTEM continued:

- **Energy Savings Potential continued:**
  - As with other HVAC equipment, more efficient products are more expensive, but payback can be achieved in a reasonable timeframe.

- **Cost Considerations:**
  - Forced air is the most common form of HVAC because of its flexibility, efficiency potential, and cost.
    - CAV systems are the least expensive to install.
    - VAV systems are about 50% more expensive than CAV systems, but provide better efficiency and zoning capability.
  - Equipment with higher energy efficiency typically has a higher first cost but can pay back and provide long term savings.
  - A life cycle cost calculation can be performed to determine the payback period once all of the project variables are known.

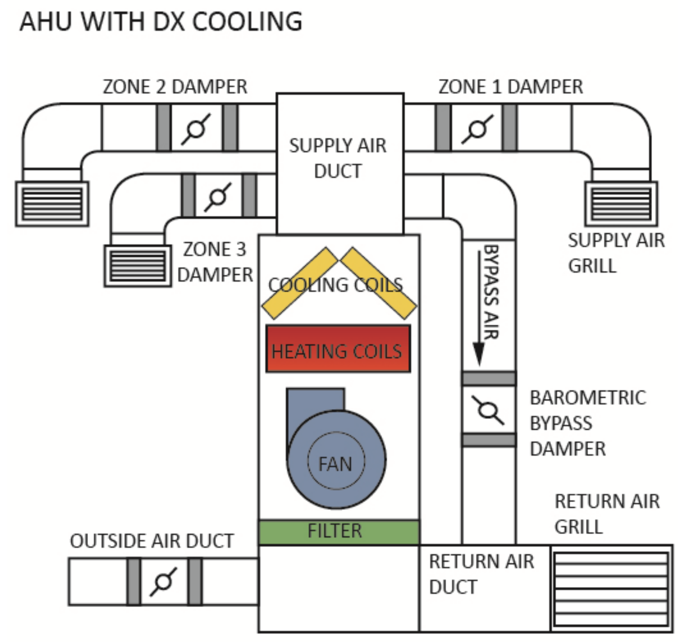


Figure 23 22-7 AHU with DX cooling

Figure 23 22-8 Rooftop Unit with DX cooling

GUIDELINE DESCRIPTION: This Guideline will discuss some fundamental differences that exist between the operations of hydronic systems as compared to all-air systems. Zone Piping consists of cooling only or heating only. The selection of piping components depends largely on the design of the system. Use in conjunction with Guideline 23 08 Selecting HVAC systems. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 22 33 Hot Water Energy Conservation
- 23 08 Selecting HVAC Systems
- 23 11 HVAC Interior Placement

GENERAL NOTES:

- There are two primary types of Heating and Cooling Pipe Systems that will be discussed below:
  - Two Pipe Systems
  - Four Pipe Systems

Terminology:

Coil: *A heat exchanger in which liquid is circulated to provide heating or cooling to the air that passes through the heat sink fins.*

Distribution: *Moving air to or in a space by an outlet discharging supply air.*

Fan Coil Unit: *Fan and a heat exchanger for heating and / or cooling assembled within a common casing.*

Figure 23 23-1 Heating Coil

CONSIDERATIONS FOR USING HOT AND COLD WATER PIPE SYSTEMS:

- **Approach:**
  - Selection of the piping components depends largely on the design of the system.
  - The coil (which could be made up of one or more units) is piped directly from the chilled water supply (CHWS) to the chilled water return (CHWR) or from heating water supply (HWS) to the heating water return (HWR) without regard to circuit length.
    - Each of these sections of supply and return piping may be controlled independently with automatic control valves on the return, allowing for control of a group of coils.
    - Isolation valves are used on the supply and return to each coil, thereby allowing them to be independently disconnected from the system for maintenance, if required.
  - Interior zones are for cooling only, and therefore only require provision of chilled water supply lines.
  - Volume regulation and any additional components to facilitate balancing or maintenance of the beams may also be required.

- **Two Pipe System:**
  - Two pipe systems contain one supply pipe and one return pipe. The supply pipe provides either hot water or chilled water throughout the building.
    - A Two Pipe System may operate as either a cooling-only or heating-only device.
      - The system uses a single coil and will provide heating or cooling depending on whether chilled water or hot water is supplied to the coil.
      - This type of system is called a changeover system, and can either be a local or system changeover.
    - A two-pipe system is usually operated in the heating mode in the winter and the cooling mode in the summer.
    - Two pipe systems cannot simultaneously heat and cool.
    - These systems are not acceptable for use in buildings where there are internal rooms with high internal gains, such as in computer rooms.

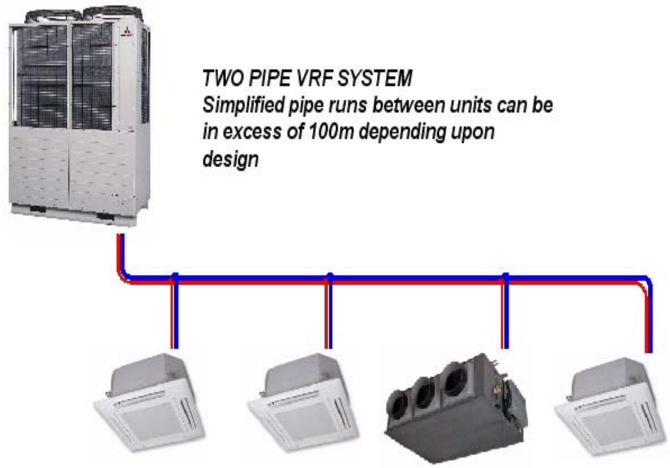


Figure 23 23-2 Two Pipe System

CONSIDERATIONS FOR USING HOT AND COLD WATER PIPE SYSTEMS continued:

- **Two Pipe System continued:**
  - Two pipe systems are less complicated than other types of hot and cold water pipe systems since they contain fewer pipes, coils, valves, and controls.
  - Two Pipe System with reverse return:
    - Total pipe length from the pump to and from each radiator is the same for all radiators on the same story.
  - Two pipe system with overhead piping:
    - Distribution pipes are located in the suspended ceiling and air vents are installed in central positions.
  - Two Pipe system with underfloor piping:
    - Very common in houses and in buildings where the piping cannot be fitted in the available ceiling space.
    - Distribution pipes are placed under the floor.
  - Pros:
    - Two-pipe systems cost less to build than more complex pipe systems.
    - Take up less room.
    - Consume less energy.
    - Easier to maintain than the standard four-pipe system. This is because they use half the piping, and half the number of pumps and actuators.
    - Installing high-efficiency equipment ensures that the short-term cost savings of two-pipe designs deliver long-term fuel savings for the life of the building.
    - When in heating mode, two-pipe systems generally deal with lower, wider-ranging water temperatures than four-pipe designs.

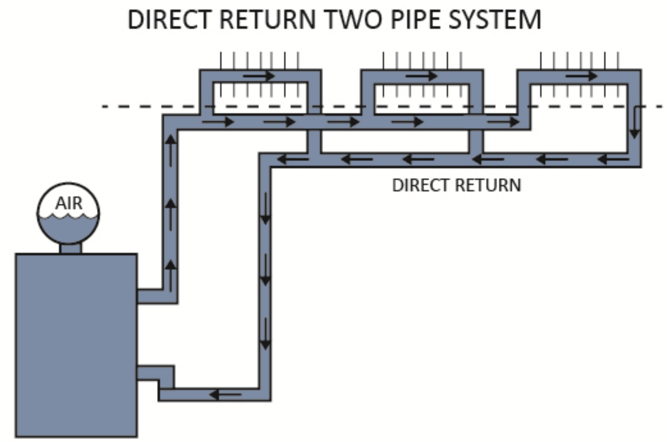


Figure 23 23-3

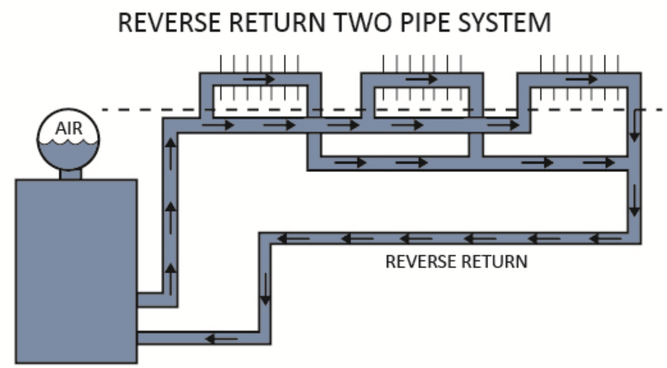


Figure 23 23-4

- **Four Pipe System:**
  - The clear advantage of a four pipe system is that each zone can supply heating or cooling as required, independent of what is being provided in neighboring zones. This provides increased flexibility and control to building occupants.
    - Control of this system requires two valves for each panel (or series of panels) to control the supply flow rate of both cold and hot water independently.

CONSIDERATIONS FOR USING HOT AND COLD WATER PIPE SYSTEMS continued:

- **Four Pipe System continued:**
  - A four pipe system has fan coil units with separate heating and cooling coils, as well as separate pairs of heating and cooling pipes.
  - Hot water or chilled water is always available.
  - The system is able to instantly switch from the heating mode to the cooling mode, or vice versa, and can provide heating to some rooms while simultaneously providing cooling to other rooms. It is very flexible.
  - Pros: Four pipe HVAC systems have a number of advantages over two pipe systems.
    - Each zone can supply heating or cooling as required, independently of is being supplied to neighboring zones.
    - Four-pipe systems have separate heating and cooling fan coil units and separate pipes for heating and cooling.
    - Hot or chilled water is always available, so the system can immediately change over from a heating to a cooling mode.
    - Two-pipe systems have to be manually switched over from cooling to heating and vice versa. This inconvenient and time-consuming process is not required in four pipe systems.
    - Four-pipe systems can cool some rooms while heating others, offering great flexibility in a building with a variety of heating and cooling needs.
  - Cons: Four-pipe HVAC systems also have a number of disadvantages compared to two-pipe systems.
    - Four pipe systems are very complicated.
    - Four pipe systems are typically around $3.00 - $4.00 per square foot more expensive to install and maintain.
    - They have twice as many valves, coils, controls and pipes to maintain.
    - These systems are twice as prone to congestion due to the increased piping.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes

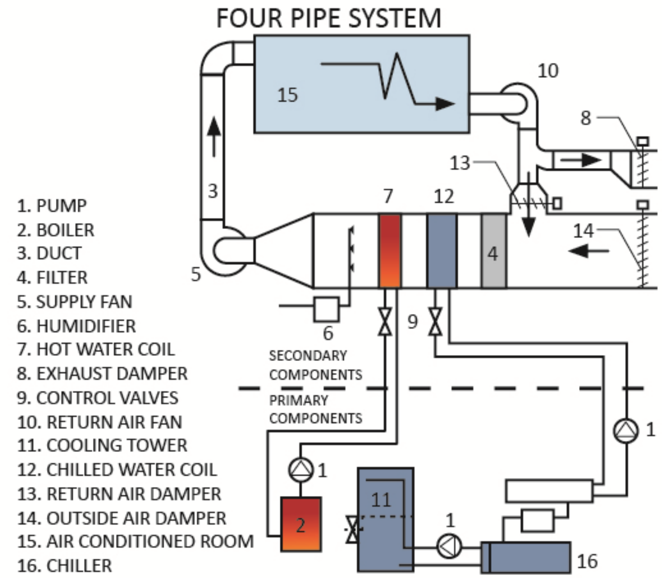


Figure 23 23-5

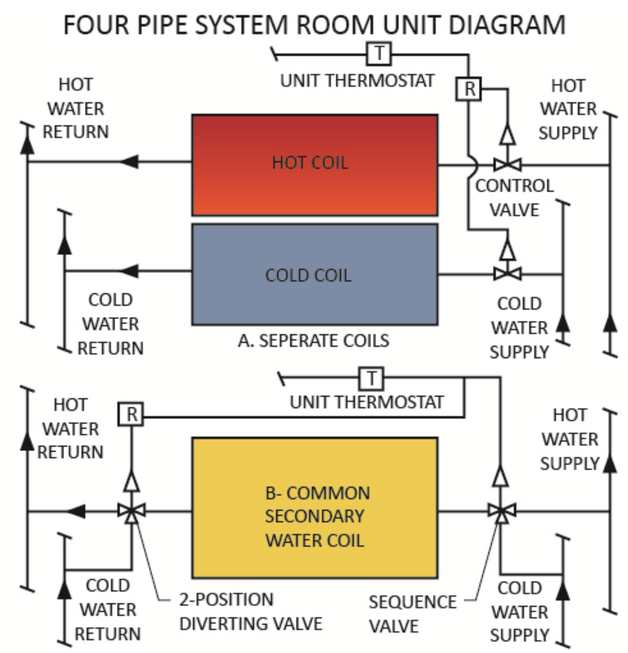


Figure 23 23-6

CONSIDERATIONS FOR USING HOT AND COLD WATER PIPE SYSTEMS continued:

- **Historic Preservation Effects:**
  - If water lines must be exposed, there can be methods to conceal the piping.
    - Furring of the walls.
    - Painting the piping to match existing ceiling and walls.
    - Recessed cabinets.
  - These are very quiet systems with minimal vibration. Therefore, they can be a good option for buildings in which there are noise related concerns.

- **Energy Savings Potential:**
  - Manufacturer and case study information from outside the U.S. indicate that heating piping systems are cost effective, but results depend on specific application features.
    - Typically, energy savings ranging from 10% to 60% are achieved, depending on climate and the type of system displaced, among other factors.
    - Initial costs are also typically higher, with payback periods dependent on energy savings.
  - Some of The energy efficiency of a heating piping system depends on all the components, including the boiler(s), piping, and radiant heaters.
    - A well designed system with efficient boiler(s) and good piping insulation can be energy efficient.
    - Boilers can range from 80% up to 95% efficient.
    - Radiant heating does not use energy to power fans but does require heating and pumping energy.
      - Fan energy is a large factor in most non-radiant HVAC systems.
      - Radiant heating alone cannot provide ventilation so operable windows or a dedicated ventilation unit are required.

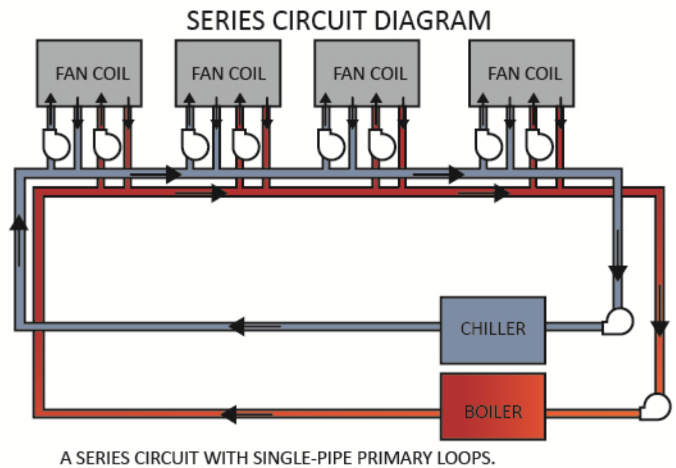


Figure 23 23-7

CONSIDERATIONS FOR USING HOT AND COLD WATER PIPE SYSTEMS continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Life-cycle cost includes several cost factors that include the following:
    - First cost
    - Operation
    - Maintenance
    - Replacement
    - Estimated energy use
  - Considering these factors, life cycle cost evaluates the total cost of the system over a period of years.
  - The usual method of comparing the life-cycle costs of two or more systems is to convert all costs to "present worth" values.
  - Life-cycle costs are most often used by institutional builders - schools, hospitals, government - and owners who expect to occupy the building for an indefinite period.
  - An HVAC system with chillers and cooling towers needs to be associated with a complete system containing the necessary piping, heating, and air distribution system.

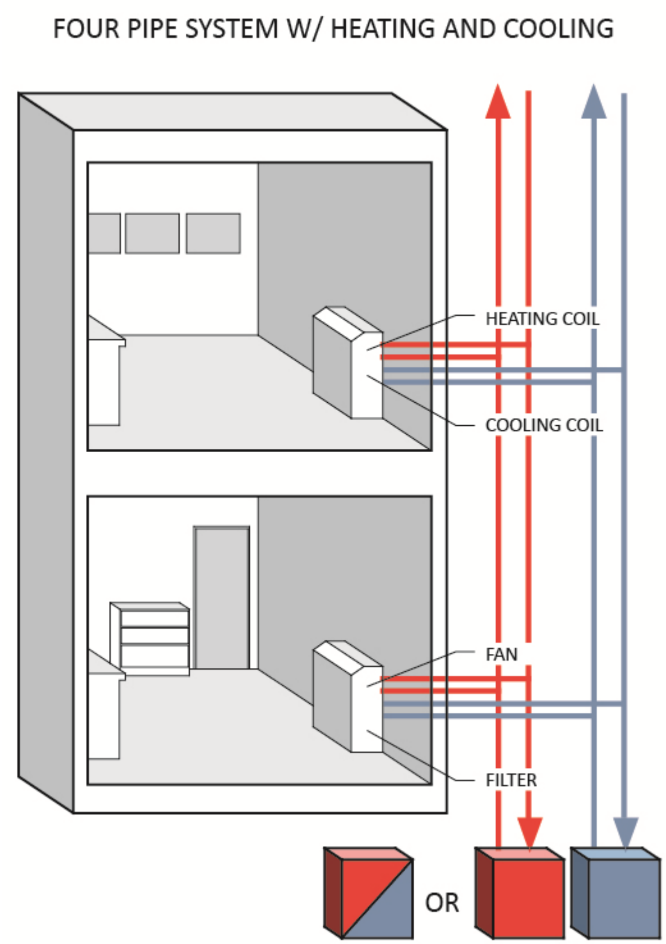


Figure 23 23-8

GUIDELINE DESCRIPTION: This Guideline will look at different types of floor heating systems (radiant heating systems) and how they can work with historic masonry floors. It will also provide a decision making process that is appropriate for historic conditions. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 07 21 Thermal Insulation, review for steps in evaluating the existing building conditions.
- 04 21 Insulating Masonry Walls, review for Basement insulation.
- 23 08 Selecting HVAC Systems
- 26 22 Radiant Electric Panels

GENERAL NOTES:

- There are three types of under floor heating systems:
    - Electric – see Guideline 26 22 Radiant Electrical Panels for a discussion on this system.
    - Hydronic (liquid-based).
    - Air-Heated – Air is a poor conductor of heat and is not yet cost effective enough to recommend.
    - All operate by conducting heat through a series of coils under the floor.
- This type of system should only be considered when significant work to the floor is being done.
- Use of a floor heating system reduces the need for a visible heating element, but can require more additional space to house the other components of the heating system.
- Typically, electric radiant heat is more efficient and feasible for retrofit / historic applications in smaller scale rooms.
- Hydronic systems are typically installed in new constructions as an integral part of the design from the beginning and can be more efficient at a larger scale.
- Advantages: more efficient than baseboards, eliminate heat loss through ducts; do not distribute allergens through the air.
- Relies on convection, the natural circulation of heat, as air warmed at floor level rises.
- Wet Installations use a large thermal mass (concrete) over a wood subfloor.

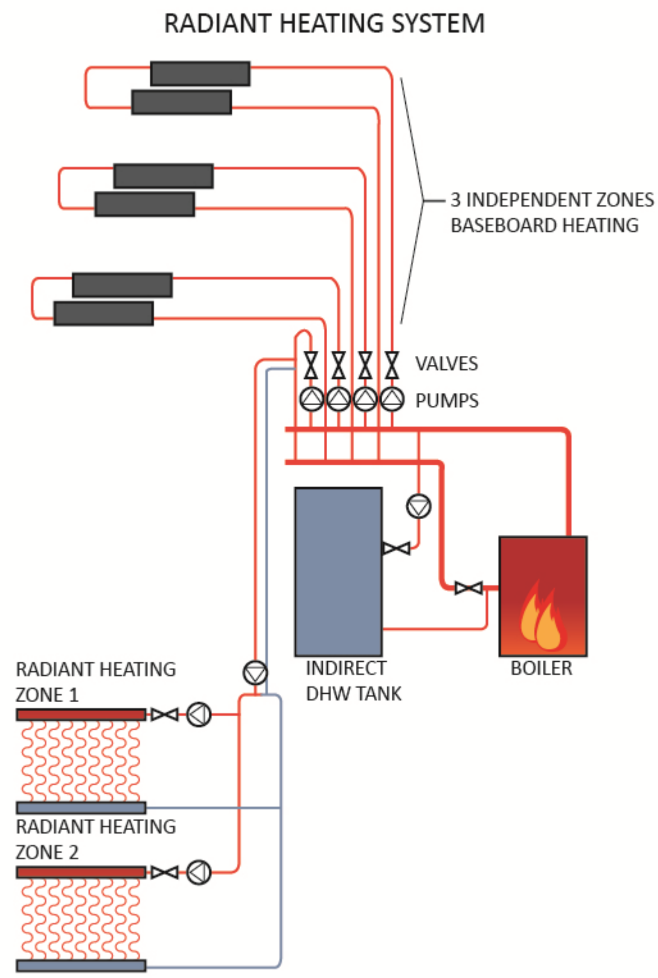


Figure 23 40-1

GENERAL NOTES continued:

- Dry installations are those in which the radiant floor tubing is placed between two layers of plywood or attached under the finished or subfloor.

CONSIDERATIONS FOR HYDRONIC SYSTEMS:

- **General Info:**
  - Use little electricity, can be a good option for remote / off-grid locations.
  - Can use a wide variety of energy sources to heat the liquid.
  - Most popular and cost-effective radiant heating system for heating-dominated climates.
  - Heated water is pumped through a series of tubes laid in a pattern under the floor.
  - The water is heated by a boiler.

- **Approach:** assumes that non-historic floors are being removed, historic floors are being removed and reinstalled, or new floors need to be installed for other reasons.
  - Determine if the existing structure can support additional loads.
  - Determine installation type:
    - Wet installations embed tubing in a concrete or lightweight concrete subfloor. Space and structural requirements must first be determined to consider this option.
      - Are ideal for use in conjunction with solar energy systems as the concrete can store significant amounts of heat.
      - A disadvantage is the slow thermal response time in the morning.
    - Dry installation is a newer technology.
      - Faster and less expensive install.
      - Air space is less efficient than concrete, so the system needs to operate at a higher temperature than in wet installations.
      - Might require drilling through joists and installing reflective insulation to direct heat upward.
  - Some systems use zoning valves or pumps and thermostats to regulate the flow of hot water to control the temperature.

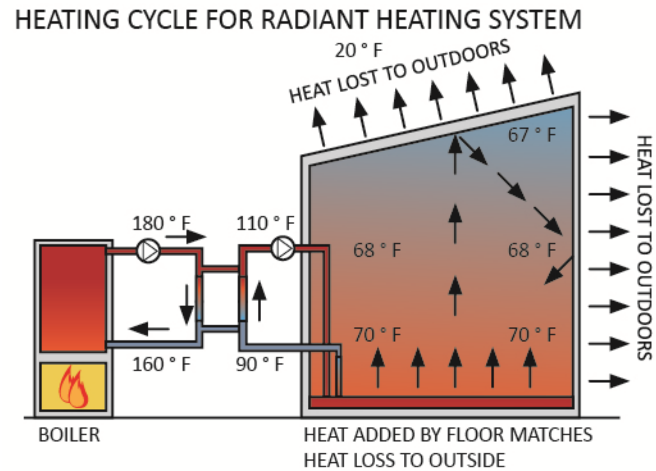


Figure 23 40-2

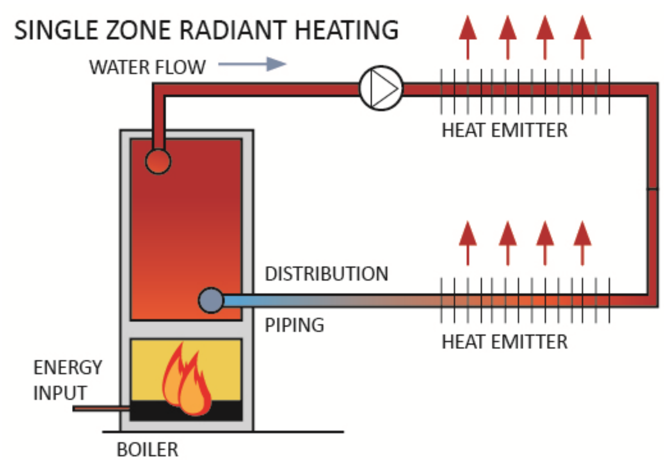


Figure 23 40-3

CONSIDERATIONS FOR HYDRONIC SYSTEMS continued:

- **Approach continued:**
  - Determine type of finish floor.
    - Concrete or ceramic tile is the most common and most effective for its conductive and thermal storage properties.
    - Sheet products, carpeting or wood can also be used.
    - Any product that insulates the floor will decrease the efficiency of the system.

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - Exposing the original, character defining structure and interior finish does not have any negative Historic Preservation Effects.
  - Careful analysis is needed to ensure that the structure is capable of handling the additional loads for a radiant floor heat system, especially if a wet installation is being considered.
  - This system requires significant work to the floor, but if space and security concerns (tampering with the air supply) are also significant considerations, this can be a feasible option.

- **Energy Savings Potential:**
  - The energy efficiency of a radiant heating system depends on all the components, including the boiler(s), piping, and radiant heaters. A well designed system with efficient boiler(s) and good piping insulation can be energy efficient.
    - Boilers can range from 80% to 95% efficient.
    - Radiant heating does not use energy to power fans but does require heating and pumping energy.

Figure 23 40-4 Electric heating mats being installed under a wood floor system.

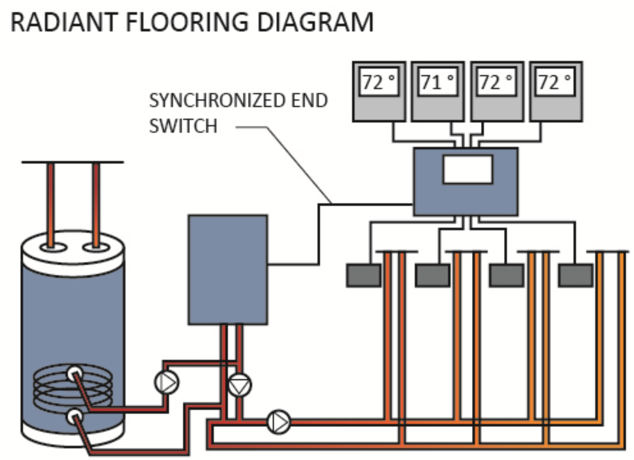


Figure 23 40-5

CONSIDERATIONS FOR HYDRONIC SYSTEMS continued:

- **Energy Savings Potential continued:**
    - Fan energy is a large factor in most non-radiant HVAC systems.
    - Radiant heating alone cannot provide ventilation, so operable windows or a dedicated ventilation unit are required.

- **Cost Considerations:**
    - Costs vary greatly from location, size of space and rooms, type of installation, floor covering, remoteness of site, and cost of labor.
    - A Hydronic radiant floor heating system is usually installed as a sole source system.
        - Hydronic radiant floor heating system costs depend on local rates, the number of temperature zones, and the overall size of the system. (CostHelper.com 2014)
    - Electric radiant floor heat is typically installed as supplemental heat in one room rather than as the main system for an entire building.
        - Electric radiant floor heating systems typically have a material cost of **$5-$7 / sf**, but their cost including professional installation depends on local rates. (CostHelper.com 2014)
        - Electric Radiant costs for a 100 sf room with a 12 watt/sf heating mat that runs 6 hours/day: (Run times differ depending on the area of the country) (HeatTechProducts.com 2013) and (STEP Warmfloor 2012).
            - 100 sf x 12 watt/sf / 1000 (KVA) = 1.2 Kwh x .09 cents/Kwh = .11 cents/hour to run the system. That .11 cents x 6 (hours run in a day) x 183 (total days used in a 6 month period = $120.78 energy cost to heat a 100 sf room.

Cost Comparison of the different types of systems		
Radiant Floor Type	**New Construction Cost**	**Heating System**
Hydronic	$6-$16/sf	Sole Source for entire building
Electric	$8-$12/sf	Supplemental heat to one room

Chart 23 40-1

Figure 23 40-6 Radiant Flooring Image from:

CONSIDERATIONS FOR HYDRONIC SYSTEMS continued:

- **Cost Considerations continued:**
    - Hydronic radiant floor heating with an electric boiler uses 3.412 kilowatts per hour to equal one BTUh. Most buildings are designed between 20 or 30 BTU/hr/sf. This number depends on the area of the country.
        - 1500 sf x 30 BTUh per sf = 45,000 BTUh. Divide the total BTUh by 3.412 Kilowatts, 45,000/3.412 = 13,188.75 (Volt Amps); Divide the total VA by 1000 13,188.75/1000 = 13.2 KVA per hour. Take the 13.2 kva per hour and multiply it by the electric utility. 13.2 KVA x .09 = $1.19 dollars to run the electric boiler per hour. If the boiler runs an average of 6 hrs per day for 30 days, the total monthly cost would be $214.20.

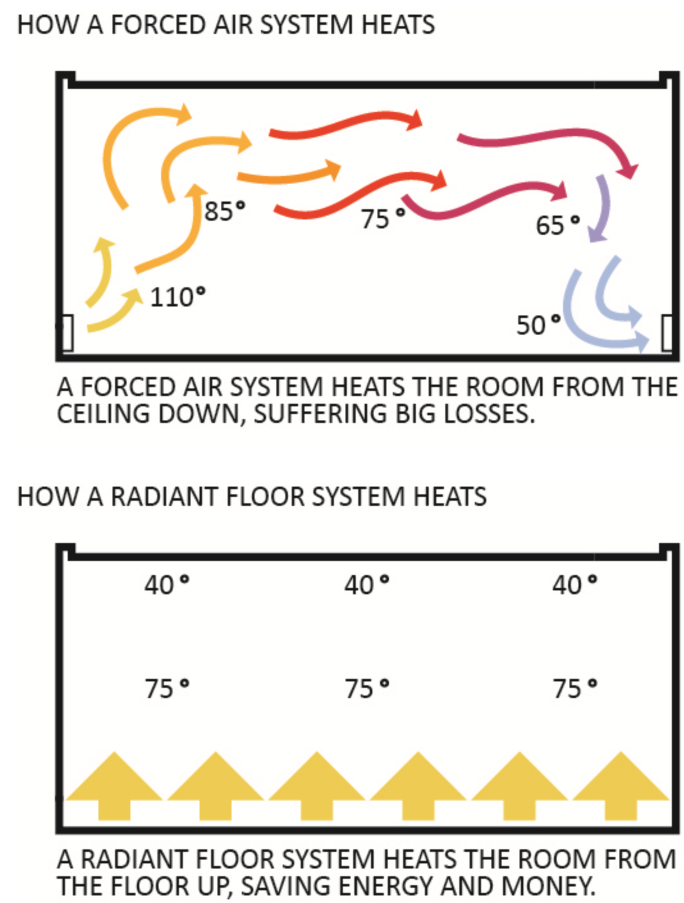


Figure 23 40-7 Diagram comparing the heat distribution between a radiant floor system and forced air system

CONSIDERATIONS FOR HYDRONIC SYSTEMS continued:

- **Cost Considerations continued:**

Heating System Comparison		Electric Radiant Heating System	Forced Air and Gas Heating System
Efficiency	Efficiency at 100% of capacity	100%	60-90%
	Efficiency at 50% of capacity	100%	30-60%
	Efficient - relative thermal	100%	50-75%
	100% of energy is delivered to the heating element	YES	NO
	Proper sized capacity of "Off Peak" conditions	YES	NO
Maintenance	Annual Maintenance Required - Clean or change filters	NO	YES
	Easy to repair	YES	NO
	Controls - simple and reliable	YES	VARIES
Cost Savings	Expandable - easily and economically	YES	NO
	Compatible with all Floor Coverings	YES	YES
	Floor space required for installation (mechanical room)	NO	YES
	Decorating limitations for furnishings, wall coverings, etc. (no registers, grills, radiators)	NO	YES
	Simple Installation and Operation	YES	NO
	Structural building cost increases required to accommodate	NO	NO
	Venting required to outside and combustion air required	NO	YES
	Concrete required - regular or lightweight	NO	NO
Remodeling	Retrofit-ability in existing concrete or asphalt	YES	NO
	Retrofit into joist space effectively	YES	NO
	Simple modification for remodeling	YES	NO
	Easy and effective for large or small areas	YES	NO
	Minimal floor section height increase (1/8" or less)	YES	YES
Health and Safety	Health & Medical (does not distribute dust, pollen, allergens through the air)	YES	NO
	Environmentally-friendly (greenhouse, glycol, etc.)	YES	NO
	Safety (no high-voltage, no hot surfaces, no combustible gases)	YES	NO

Chart 23 40-2

GUIDELINE DESCRIPTION: This Guideline discusses installation and location of solar photovoltaic panels for electrical energy on roof and ground systems to insure the integrity of the historic building and surrounding areas. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 22 33 Hot Water Conservation

GENERAL NOTES:

- Part 1 assumes that the owner is considering a Solar Photovoltaic (PV) Panel System.
- Part 2 assumes that the owner has done the previous steps and is now considering installation.
- Part 3 provides Applicable SOI Standards, Historic Preservation effects, Energy Efficiency Potential and Cost Considerations that apply to all applications of PV panel installation.
- The Guideline then goes on to discuss the differences between different installations.

PART 1: (National Renewable Energy Laboratory 2012)

- Analyze whether the installation of solar PV system will benefit a historic building or site without compromising its character with the CRM and/or SHPO.
- Analyze Site Location
  - Building orientation to due south is the most ideal
  - Building location in relation to obstacles that may interfere with PV production, such as trees, roof equipment and nearby buildings.
  - Determine retrofitting of solar panels will not alter the buildings architectural integrity
- Contact/work with the applicable Stakeholders in the project
  - Federal agencies overseeing cultural resource regulations in the area of construction
  - Local preservation commissions
  - Local government
  - Adjacent property owners
  - Contractors
  - Engineers
  - Planner
  - Utility company

Why to consider a Photovoltaic System

1. *Reduce energy grid consumption*
2. *Provide a renewable energy source*
3. *Meet LEED certification requirements*
4. *Owner motivations*

Common Terms when discussing Photovoltaics:

Array – *Solar panels arranged in a group to capture sun light to convert it into usable electricity*

Free standing / Stand alone system – *Electrical system which receives its power from solar panels which are independent of the utility grid. System may be used in conjunction with batteries and wind turbines.*

Grid-tied – *Solar panels which are connected to the facility electrical system and the utility grid, with excess power being fed back to the utility.*

kWh – *Kilowatt-hours, how electricity is measured*

Off-grid – *Same as Free standing/Stand alone*

Tracking System – *Solar panels mounted on a tracking system that maintains the optimal angle to the sun to provide the maximum efficiency from the solar panels*

ART 2: INSTALLATION CONSIDERATIONS

- **Components:** Solar photovoltaic systems consist of solar modular panels, disconnect switches, inverters, utility disconnect. Off-grid and/or back up system also consist of batteries and charger controller. (National Electrical Code, Article 690 Solar Photovoltaic (PV) System). The main component considerations for Historic buildings and structures are the type of panel and the mounting system.
  - Three main types of panels (U.S. Department of Energy, National Renewable Energy Lab): Discuss with Design Team and chose type based on Efficiency, Cost, Manufacture, Warranty and Aesthetics.
    - Single Crystal: Made from silicon, usually flat-plate and is 14-19% efficient.
    - Multi-Crystalline: Similar technology to single crystal but are only 13-17% efficient
    - Thin-film: Made from amorphous silicon or non-silicon material and the least efficient at 6-11%
  - Solar Panel mounting system (has the biggest impact on Historic Preservation): Mounting types should be based on the area that will be needed to accommodate the number of panels which will provide the Kwh needs per each project.
    - Permanently affix array to roof
    - Free standing, pole mounted
    - Free standing, pole mounted with tracking system
    - Ground mounted
  - Secondary Components/Considerations (engineer responsibility).
    - Determine Solar Panel voltage needed
      - Grid tied applications uses either 18 or 42 volts
      - Off –Grid system uses either 12 or 24 volts
    - Combiner box: Allows multiple solar panels to be combined in parallel
    - Solar Charger Controller: Regulates the amount of current PV feed into battery
    - Batteries: Storage of PV modules voltage, Common voltages are 6 and 12 volts
    - Solar inverters: Take (DC) voltage from PVs or batteries and turns it into (AC) voltage
    - DC / AC Disconnects: from the DC and AC voltage to the PV system

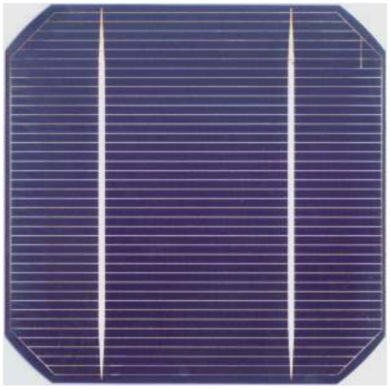


Figure 26 01-1 Single Crystal Silicon Panel

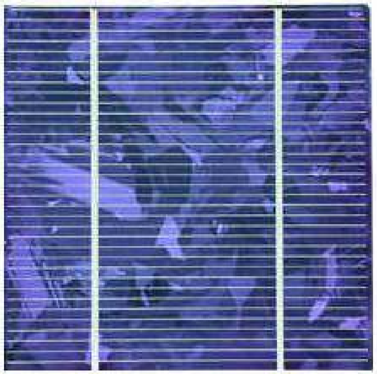


Figure 26 01-2 Multi-crystalline Silicon Panel

Figure 26 01-3 Thin-film/Amorphous Silicon Cells

PART 2: INSTALLATION CONSIDERATIONS

- **Site Installation Considerations:**
  - In Part 1, it should already have been determined:
    - If it is feasible to install free standing solar panels on the site.
    - Panel orientation (due south is best in the northern hemisphere)
    - Where minimal shading occurs between 0900 and 1500 for peak performance
  - Determine if a tracking system is needed
  - Determine visibility of panels from the public right of way
  - Location may encroach onto other historic sites in the area.
  - Distance between the solar panels and the historic building may be a concern due to voltage drop in the feeder conductors.
  - Determine the routing of underground conduit runs so not to damage historic sites

- **Grid connected and net metering:** Benefits for a grid connections is that there is no additional cost for providing batteries and/or a generator back up power. One will often generate more electricity than one is capable of consuming which gives the excess electricity produced to the utility which lowers one's electric bill. It is the least expensive solution. (EnergyInformation.org 2012)
  - A grid-connection solar PV system receives back-up power from a utility grid when the PV system is not producing enough power
  - Under a net metering arrangement the utility company essentially pays the building owner a retail price for electricity that the building system feeds back into the grid.

GRID TIED PV SYSTEM

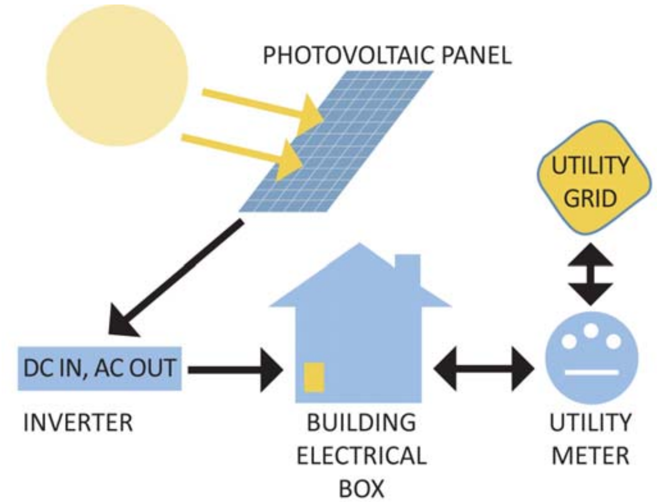


Figure 26 01-4

PART 2: INSTALLATION CONSIDERATIONS continued

- **Off-Grid and/or Battery backup:** Benefits for an off-grid connection include that it may be cheaper than a grid connection, depending on the building proximity to the closest existing utility grid. This would need to be determined based on the cost of batteries per Kwh requirements and the cost of the extension per area. Average cost per a ½ mile of utility line extension is approx. $30,000. Off-grid PV systems offer the satisfaction of self-sufficiency. Utility power failure will not affect the building. (EnergyInformation.org 2012).
  - On cloudy days or in facilities with night time operations, the owner will need to determine if a battery backup system can benefit the facility by protecting sensitive equipment or allowing operations to continue during utility power outage. Cost of the batteries, based on the facility load, will play a big role in determining the amount of backup time needed
  - If a facility is completely off-grid with no utility power available, battery backup can provide power to the electrical system for night time operation.
  - The cost of batteries is a major factor in determining whether or not backup power is needed. Another factor is whether or not there is adequate space available to house the batteries.

OFF-GRID PV SYSTEM

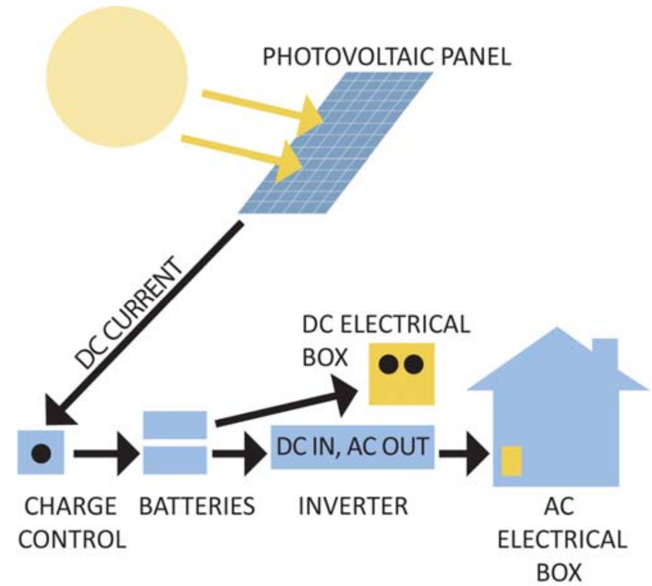


Figure 26 01-5

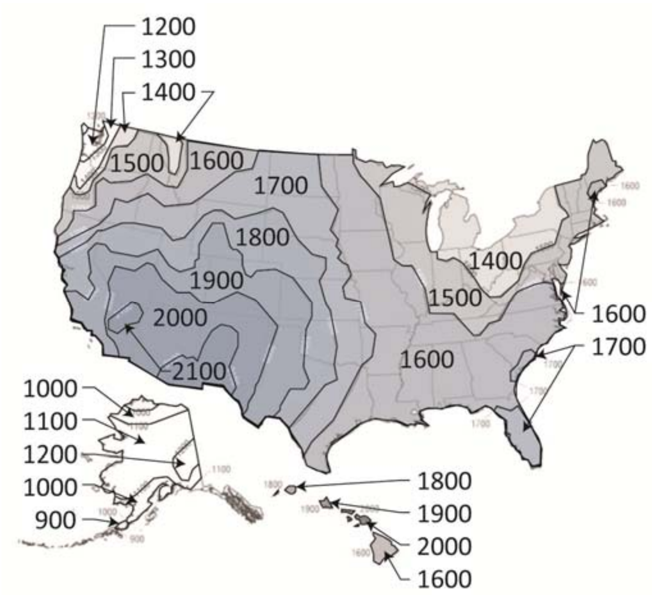
PART 3: APPLY TO ALL INSTALLATIONS TYPES

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 9: New Work is compatible with Historic

- **Historic preservation effects:**
  - The angle of installation has a direct effect on the historic character of the building.
    - Mounted flush has the least impact but can affect energy production.
    - Angled to the sun would be more visible, thus affecting the historic character.
    - A balance must be reached between Historic Preservation and Energy Savings.
  - New conduit from PV system to and within the building can damage interior historic elements. Such endeavors must be taken with careful planning.

- **Energy savings potential:** (U.S. Department of Energy, Energy Saver n.d.)
  - Use the equation below to estimate annual electricity production and electrical savings for a *Grid-connected small solar electric system* with a *net metering arrangement.*
  - **Inputs Needed:**
    - The photovoltaic (PV) system size in kilowatts (kW) ________________________kW
    - Select the energy production factor, based on geographic location. See adjacent map ________________kWh/kW-year
    - Electrical rate (commercial) found in Electric Bill ____________________$ per kWh
  - EQUATION: PV system Electricity production =(kW of PV) x (Commercial Rate) = $/years
  - EXAMPLE: a 9.3 kw system (kW of PV) in Albuquerque , NM , at an average Commercial energy rate of 10 cents/kWh will save $1,953 per year: (10 cents/kWh based on US average from U.S. Energy Information Administration 2012)
    - 9.3kW x 2100 kWh/kW-year x $0.10 kWh =$1,953 (or $162.75/month)

Energy Production Factor Map in kWh/kW-year



Note: The uncertainty of the contoured values is generally +/- 10%. In mountainous and other areas of complex terrain, the uncertainty may be higher. See Appendix H for a larger version of this map.

Figure 26 01-6

  - Operating an *Off-Grid PV system with battery backup or Generator (Stand-Alone System)* may or may not be cost-effective depending on the cost to run a power line from the existing electricity grid and the size of the battery bank required.
    - The battery bank backup system should be sized to provide power for a minimum of 5 days without recharging.
    - An Off-Grid system is specified when independence from the power provided is desired or required. It also demonstrates a commitment to non-polluting energy sources.
    - Commercial Off-Grid system will be range from 5 to 10 kw or larger, depending on the type business.

PART 3: APPLY TO ALL INSTALLATIONS TYPES

- **Cost considerations:**
  - **Determining system size:** Estimate the size of solar array needed (Solar Power Authority):
    1. Calculate the kWh per day, this can be accomplished in two ways:
       a. Calculating by using the monthly electric bill
          - Total kWh used from monthly bill for one year. ____________
          - Divide by 12 (months / year) to determine average monthly kWh usage. ____________
          - Divide 30 (average days in a month). This will determine daily kWh usage. ____________

       b. Calculating usage by listing the power consumption for each appliance to get the total kWh usage per day. Recommend creating an excel table for this option.
          - List all the electrical appliances in the facility.
          - List the wattage from the equipment name plate. If the equipment only lists the equipment Volts and Amps, multiply Volts x Amps which equals Watts.
          - List the hours in a day the equipment is used.
          - Take each piece of equipment and multiply it by its Watts, then multiply that by Hrs/Day used. This will give the total kWh usage for that equipment per day.
          - Total all the kWh for each piece of equipment and that will give the daily kWh usage and/or the total kWh goal.
    2. Determine total kWh goal (desired production of the system) ____________
    3. Determine Insolation hours kW (total number of hours in a day the PV panel will produce its rated voltage, depending on the area of installation) ____________
       - Location specific, use http://aom.giss.nasa.gov/srlocat.html (NASA and GISS)
    4. Determine the number of kW needed to be produced per hour to reach kWh goal Goal kWh (Step 2) divided by Insolation hours (Step 3) ____________
    5. Determine Energy losses (Multiply kW in Step 4 by 1.3) ____________
       - A PV system will lose up to 30%, increase kW size by 1.3 to account for this loss
       - **This number shows how much is needed to meet the target kWh goal per day.**

Determining System Cost Example

1. Calculate kWh/day using first option:

a. Total kWh for 1 year = 11,808 kWh/year

b. Monthly 11,808/12 = 984kWh/month

c. Daily usage 984/30 = 32.8 kWh/day

2. Determine daily kWh goal= 36 kWh

3. Determine Insolation hours for Albuquerque, NM = 5 hrs

4. 36kWh/5hrs =7.2 kW

5. Energy Loss 7.2kWx1.3 = 9.3kW

Therefore, the example project will need a 9.3 kW (or 9,300 Watt) system to produce 36 kWh per day.

The installation cost for the example system at $6.30 to $8.49 per Watt would be approximately $58,590 - $78,957 (U.S. Department of Energy, Berkeley Lab).

PART 3: APPLY TO ALL INSTALLATIONS TYPES

- **Cost considerations continued:**
  - **System Costs:**
    - Grid connected PV system payback – With the lower end cost for a 9.3 kW PV system at $58,590 (see previous page example and link). This includes solar panels, fixed roof mounting, invertor, wiring, fuses, switches, etc. for a complete system.
    - Off-Grid PV system with Battery backup payback – With an estimated cost for a 9.3 kW PV system at $82,890 ($9.10/watt). Cost – PV system @ $6.30/watts, 5 day battery bank @$15,000, Invertor @ $9,300 = $82890. This includes solar panels, fixed roof mounting, invertor, 5 days battery bank, wiring, fuses, switches, etc. for a complete system (Infinite Power of Texas 2012).
  - **Utility extension**
    - A 1000’ new overhead utility line extended from an existing primary pole will cost approx. $11,850 (Consumers Power Inc. 2012).
  - **Calculating PV System Payback for Grid Connected and Off-Grid PV Systems:**
    - Calculate the cost for the PV system including installation costs, and deduct all Federal and State incentives from the total.
    - Determine the initial annual savings from the PV System: Calculate the output of the proposed system in kilowatt hours and determine what percentage the PV system will save in energy cost per year.
    - Set assumption regarding future increase in electric costs: A conservative estimate assumes that the electricity rates will increase at a rate of 4% per year for the next 25 years.
    - Multiply the annual saving by energy inflation rate: Multiply the amount of savings after year 1 by 1.04 for each year for the next 25 years.
    - Accumulate the savings by year: Add the prior year’s saving to the current year’s saving for each year. Add amount of any pay-back to the owner for the kWh generated and sold back to the utility company.
    - Subtract the initial cost from the accumulated savings.
    - For more information, go to: energybible.com/solar_energy/typical_costs.html

National Renewable Energy Laboratory (NREL) GIS maps, 2011 data

Figure 26 01-7 Simple Payback for PV Systems with Incentives

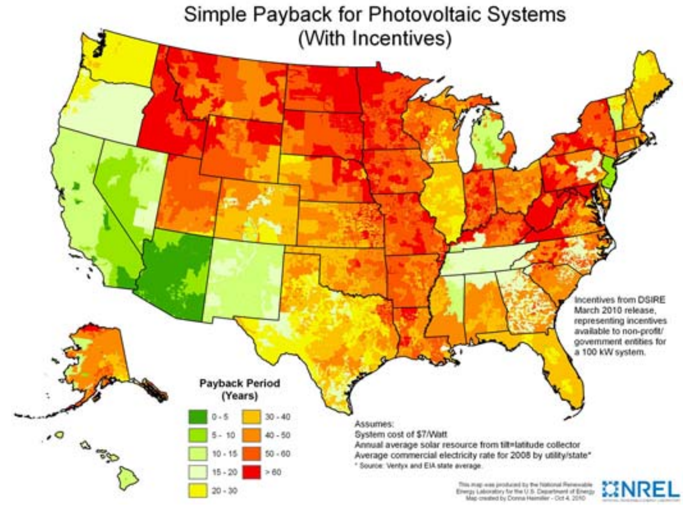
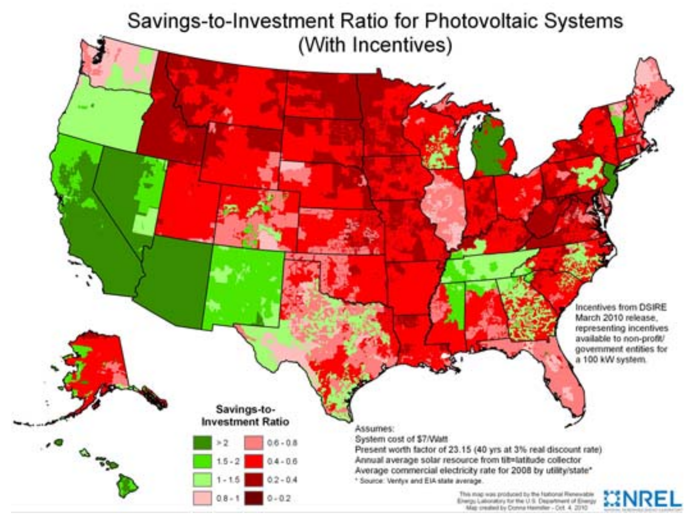


Figure 26 01-8 Savings-to-Investment Ratio for PV Systems with Incentives



See Appendix I for larger versions of these maps

PART 3: APPLY TO ALL INSTALLATIONS TYPES

- **Cost considerations continued:**
  - **Mounting system and installation cost:** (Tracking the Sun IV: An Historical Summary of the Installed Cost of Photovoltaics in the United States from 1998-2010)
    - Fixed tilt array on the roof, pole and ground mounted system cost is approximately $0.70/watts of the total cost per watt
    - Solar tracker mounting system will add approximately an additional 19% to the total cost per watt.
  - **Residential and Commercial PV Systems are eligible for Federal and State Incentive Programs:**
    - The Federal Government offers a business energy investment tax credit program with up to 30% tax credit for PV systems. For more information, go to : http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F&re=1&ee=1
    - The Federal Government offers a Residential Renewable Efficiency Tax Credit program with up to 30% tax credit for PV systems. For more information, go to: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US37F&re=1&ee=1
    - State by State incentive programs widely range from tax credits, and sales and property tax deductions. Each individual will need to contact their state government to determine what incentive programs, if any, are available. For more information, go to: http://www.dsireusa.org/
  - **Residential and Commercial PV Systems are eligible for Local Utility Company Incentive Programs:**
    - Utility incentive programs provide a wide range of programs depending on the size of the PV system.
    - California Pacific Power provides an incentive program which offers from $1.13/Watt for residential systems to $0.36/W for Commercial systems, sized between 1kW and5kW. For more information, go to: http://www.dsireusa.org/
    - New Mexico PNM has an incentive program with a range of $0.04/kWh for small systems, sized up to 10 kW, to $0.05/kWh for larger systems, sized between 10 kW to 100 kW. For more information, go to: http://www.dsireusa.org

National Organizations and Resources

DSIRE *is the Database of State Incentives for Renewables and Efficiency under NREL subcontract no. XEU-0-99515-01 www.dsireusa.org*

Energy Bible *is a non-governmental website "dedicated to providing the public with up-to-date information on renewable energy." Energybible.com*

IREC *is the Interstate Renewable Energy Council, a non-profit organization. www.irecusa.org*

NREL*is the National Renewable Energy Laboratory of the U.S. Department of Energy www.nrel.gov*

CONSIDERATIONS FOR INSTALLING A PV SYSTEM ON A FLAT ROOF WITHOUT A PARAPET:

- **Approach:**
  - Panels can be mounted flush, parallel and flat on roof
    - Least visible, therefore, least impact on the historic character
    - Installing panels flat on roof may reduce the maximum electricity production due to the angle of the panels to the direction of the sun.
  - Locate in the rear of the building to further reduce the visibility of panels
  - Determine location of inverters, disconnect switches and metering device
    - Coordinate the location of the metering device and utility disconnect switch with the local utility company
    - Preferred location of inverter and disconnect switches would be adjacent to the incoming service and/or electrical room
  - For off-grid systems, determine the location of the battery bank or generator
  - Determine conduit routing on the roof and through the building to related Solar PV system equipment
    - Maintain the building integrity
    - Minimizes the routing of conduit on the exterior walls.
  - Verify if roof structure is capable to handle the additional weight of the PV system
    - Consult with a Structural Engineer who is experienced with the structural system of the specific historic structure.

- **Additional/ Specific Historic Preservation Effects: also see page 250**
  - Install solar PV panels in a manner that does not damage historic roofing material

Figure 26 01-9

PVs mounted on a flat roof without a parapet.

Note: PV panels must be installed flat or mostly flat as there is no parapet to block the view.

CONSIDERATIONS FOR INSTALLING A PV SYSTEM ON A FLAT ROOF WITH A PARAPET:

- **Approach:**
  - Parapets allow for more installation options since panels can be hidden by the parapets:
    - Panels can be mounted flush
    - Panels can be mounted vertically or horizontally, depending on parapet height
    - Panels can cover a large roof area, since panels are more easily hidden
    - Panels can be tilted towards the sun to maximize the electricity production
  - Determine location of inverters, disconnect switches and metering device
    - Coordinate the location of the metering device and utility disconnect switch with the local utility company
    - Preferred location of inverter and disconnect switches would be adjacent to the incoming service and/or electrical room
  - Determine conduit routing on the roof and through the building to related Solar PV system equipment
    - Maintain the building integrity
    - Minimizes the routing of conduit on the exterior walls.
  - Verify if roof structure is capable of handling the additional weight of the PV system
    - Consult with a Structural Engineer who is experienced with the structural system of the specific historic structure.

- **Additional/ Specific Historic Preservation Effects: also see page 250**
  - Install solar PV panels in a manner that does not damage historic roofing material

Figure 26 01-10
PVs mounted on a flat roof with a parapet.
Note: PV panels can be mounted at a slight angle as the parapet will serve to block visibility.

CONSIDERATIONS FOR INSTALLING A PV SYSTEM ON A HIPPED OR GABLED ROOF:

- **Approach:**
  - Panels can be mounted flush on roof
  - Panels may be visible from public right of way
  - Panels should be mounted on the back roof section of the building to provide minimal visibility of the solar panel from the public right of way
  - Minimizes the area in which panels can be located
  - Preferably the back roof section should be facing south to maximize the electricity production.
  - Determine location of net metering device
    - Coordinate the location of the device with the local utility company
  - Determine conduit routing on the roof and through the building to related Solar PV system equipment
    - Maintain the building integrity
    - Minimizes the routing of conduit on the exterior walls.
  - Installing solar PV panels in a manner that does not damage historic roofing material
  - Verify that roof structure is capable to handle the additional weight of the PV system
    - Consult with a Structural Engineer who is experienced with the structural system of the specific historic structure.

- **Additional/ Specific Historic Preservation Effects: also see page 250**
  - Mounting PV panels on a Hipped or Gabled roof will be visible from at least one angle, which will impact the historic character of the building or structure.
    - This approach must be carefully considered with the CRM and SHPO.
  - Install solar PV panels in a manner that does not damage historic roofing material

It is the position of this document that the cultural resource impact would be too great to recommend this approach as a viable option for installing a PV system on a historic building or structure.

Figure 26 01-11
PVs mounted on a sloped roof.
Note: Not a viable option on a historic building or structure.

CONSIDERATIONS FOR INSTALLING A FREE STANDING PV SYSTEM:

- **Approach:**
  - First, investigate and determine if it is feasible to install a free standing PV system.
    - Is there the space required for the size of system desired?
    - How does the separate PV system structure impact the historic character of the historic building, structure or site?
    - What would the distance be between the solar panels and the historic building?
      - May be a concern due to voltage drop in the feeder conductors.
      - May be an additional expense
  - If it is feasible:
    - Determine if a tracking system is needed or will a stabile system suffice
    - Panels should be orientated due south in the northern hemisphere, angle to the ground depends upon latitude of the site
    - Determine the routing of underground conduit runs so not to damage historic sites
    - Locate panels in areas that will not be shaded between the hours of 9 a.m. – 3 p.m. for peak performance.

- **Additional/ Specific Historic Preservation Effects: also see page 250**
  - This option is potentially both the most visible and least impactful installation technique. It leaves the historic building completely intact, and by its nature clearly represents its own time.
  - Location may encroach onto other historic sites in the area.
    - Consider the entire site and surrounding area for potential impact.
    - If the building that the PV system supplies is part of a larger historic site or district, this option could have a significant impact on the character of the entire area.

It is not recommended to install a free standing PV system in a historic district or historic landscape if visible from public rights of way or public paths. According to the NPS, a historic district "possesses a significant concentration, linkage, or continuity of sites, buildings, structures, or objects united historically or aesthetically by plan or physical development." (NPS website). Therefore, the site and greater environment of any alterations are important, and the addition of a free standing PV system could significantly alter, detract from, or reduce the integrity of the associated historic district.

Figure 26 01-12
Free standing solar tracking array.
Note: Not recommended in a historic district or historic landscape if visible from public right of way or public paths. But, they may be a good option for a historic building if the array can be installed far enough away from the building so as not to detract from its historic character.

GUIDELINE DESCRIPTION: This Guideline will look at the installation of electrical baseboard heating to insure the integrity of the historic building. General information is presented on thermal comfort and building energy use. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 00 03 Major Preservation and Energy Issues
- 23 08 Selecting HVAC Systems
- 23 11 HVAC Interior Placement

GENERAL NOTES:

- Part 1 assumes that you are considering an Electric Baseboard Heating system.
- Part 2 assumes that you have done the previous steps and are now considering installation.
- Part 3 provides applicable SOI standards, Historic Preservation effects, Energy Efficiency Potential and Cost Considerations to all applications of the Electric Baseboard Heating.

CONSIDERATIONS FOR USING ELECTRIC BASEBOARD HEATING SYSTEMS (PART I):

- **Approach:**
  - Analyze whether the installation of an Electric Baseboard Heating system will benefit a historic building without compromising its character.
  - Analyze the existing building heating and electrical distribution system.
    - What other heating systems are available within the facility?
    - Can the existing systems be expanded at a comparable cost to the installation of an electric baseboard heating system?
    - Is the existing electrical distribution system capable of handling new loads?
  - Contact / work with the applicable Stakeholders in the project:
    - Federal agencies overseeing historic preservation regulations
    - Local preservation commissions
    - Local government
    - Contractors
    - Engineers and Planners
    - Utility company

Figure 26 21-1 Baseboard heater panels can be designed to fit within the historic context of the project.

BASEBOARD HEATER HEAT DISTRIBUTION

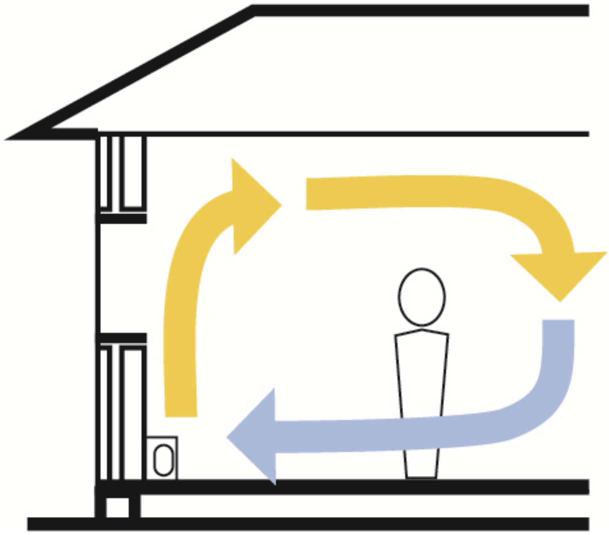


Figure 26 21-2

CONSIDERATIONS FOR INSTALLATION OF ELECTRIC BASEBOARD HEATING SYSTEMS (PART 2):

- **Approach:** (Energy.gov 2014)
    - **Components:** Electric Baseboard heaters consist of electric heating elements encased in metal pipes. The pipes are surrounded by aluminum fins to aid heat transfer along the length of the baseboard heaters. The pipe is located within a metal cabinet. Baseboard heaters are controlled from a local in-line voltage thermostat at the baseboard, or remote line-voltage or low voltage thermostats installed on an interior wall.
        - Electric baseboard heaters should be mounted on the exterior wall under a window and sit at least three-quarters of an inch above the floor or carpet. This allows the cooler air on the floor move under and through the radiator fins so it can be heated. The heater should also fit tightly to the wall to prevent warm air from convecting behind it and streaking the wall with dust particles.
        - The quality of baseboard heaters available varies considerably. Cheaper models can be noisy and often give poor temperature control. Look for labels from Underwriter's Laboratories (UL).
        - Secondary Components/Considerations (engineer responsibility):
            - Determine the area where the baseboard heaters and cables need to be located.
            - Calculate the length of baseboard heater needed to heat the area.
                - Approximately 5-8 watts of electric heat per square foot of the room.
                - Provide about 250 watts of electric heat per foot of baseboard length.
            - Determine if the existing electrical service is sufficient to handle the additional load based on the length of baseboard.
            - Controls. Determine thermostat location: baseboard or remote wall mounted.
            - Thermostat voltage: Line voltage (120 or 240 V) or low voltage (12 or 24 V).
            - Circuit extension: Determine routing of the conduit and conductors so not to damage the historic character of the interior walls, floor, and ceiling.

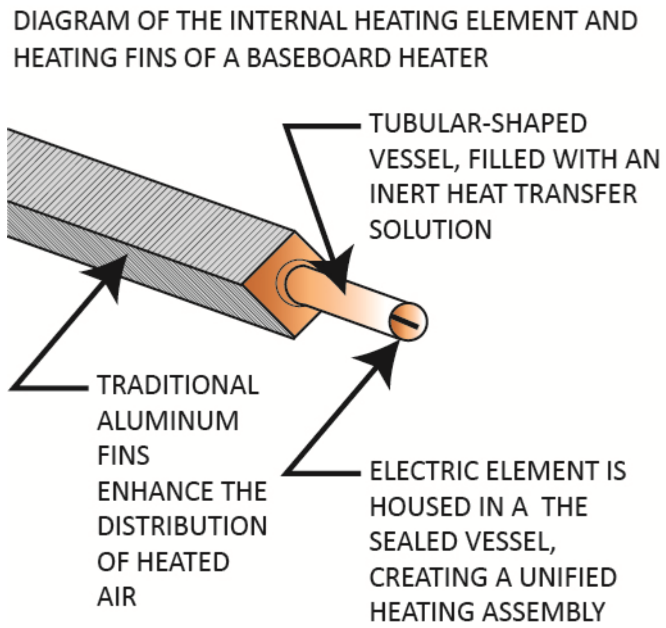


Figure 26 21-3

Figure 26 21-4 Electric baseboard heater showing the recommend installation location.

CONSIDERATIONS FOR INSTALLATION OF ELECTRIC BASEBOARD HEATING SYSTEMS (PART 2) continued:

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:** (Old House Web 2014)
  - Each building and its needs must be evaluated separately. Every effort must be made to protect the historic elements.
  - Special climate needs for historic materials must be evaluated to determine if electric baseboard heating can be used.
  - Determine which method of installation of the baseboard heating system within the facility will cause minimal damage to the surrounding structures.
  - Compare the baseboard heating system to the installation of an HVAC or climate control system that may require the addition of new structural elements to support the heavier equipment, the vibration from large equipment, and the introduction of moisture in the building.

- **Energy Savings Potential:** (Energy.gov 2014) Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - Electric resistance heating converts nearly 100% of the energy in the electricity to heat. However, most electricity is produced from coal, gas or oil generators that covert only about 30% of the fuel's energy into electricity.
  - Electric heat is more expensive than heat produced using combustion appliances, such as natural gas, propane, and oil furnaces.
  - Electric radiant heating may make sense for an addition if it is not practical to extend the existing heating system to supply heat to a new addition.

ELECTRICAL WIRING DIAGRAM FOR AN ELECTRIC BASEBOARD HEATING SYSTEM

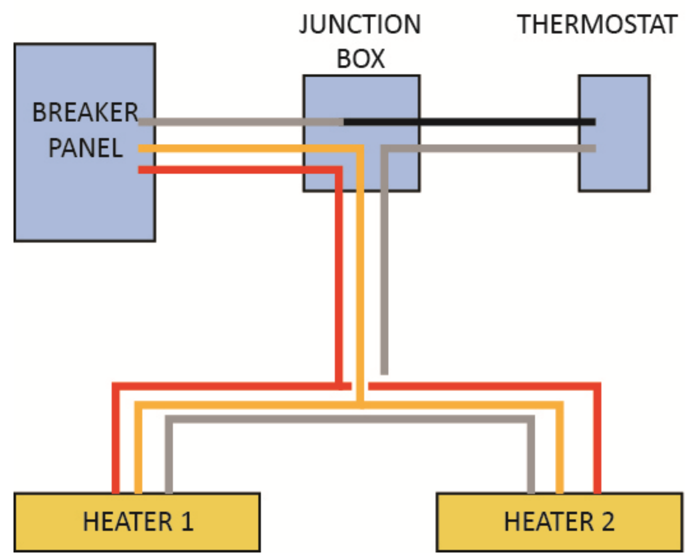


Figure 26 21-5

CONSIDERATIONS FOR INSTALLATION OF ELECTRIC BASEBOARD HEATING SYSTEMS (PART 2) continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Electric baseboard heating systems are not as common as they once were because of the rising cost of electricity and because most buildings now require both heating and cooling. The combination of both systems can be used depending on the size of the rooms and accessibility of routing ductwork within a historic building.
  - The installation of electric baseboard heating may require an upgrade to the electrical distribution system, incoming utility electric service, and additional electric branch circuit panelboard. The accessibility of running new electrical branch circuiting to the electric baseboard heater may not be possible due to the face of the historic structure.
  - The average cost per unit with professional installation is approximately $125.00 for a 3’ unit up to $300.00 for a 10’ unit.
  - To determine the estimated electric heating cost, multiply the total kilowatts for the heater by the price per KWH. The cost per kilowatt hour can either be optioned from an electric bill or from contact with the local electric company.

Example:
A 2.0 kilowatt (KW) heater at $0.10 per kilowatt hour (KWH) cost 2.0 time 0.10, which equals $0.20 per hour to operate.

If you operate your heater for 10 hours a day at a cost $0.20, you will pay $2.00 a day to run the heater. For a 30 day time frame is will cost you $60.00 to run the heaters.

GUIDELINE DESCRIPTION: This Guideline will look at the installation of electrical radiant heating to insure the integrity of the historic building. General information is presented on thermal comfort and building energy use. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 00 03 Major Preservation and Energy Issues
- 23 08 Selecting HVAC Systems
- 23 11 HVAC Interior Placement

GENERAL NOTES:

- Part 1 assumes that you are considering an Electric Radiant Heating system.
- Part 2 assumes that you have done the previous steps and are now considering installation.
- Part 3 provides applicable SOI standards, Historic Preservation effects, Energy Efficiency Potential and Cost Considerations to all applications of the Electric Radiant Heating.

CONSIDERATIONS FOR USING RADIANT ELECTRICAL PANELS (PART I):

- **Approach:**
  - Analyze whether the installation of an Electric Radiant Heating system will benefit a historic building without compromising its character.
  - Analyze existing building heating and electrical distribution systems.
    - What other heating systems are available within the facility?
    - Can the existing systems be expanded at a comparable cost to the installation of a radiant electric panel heating system?
    - Is the existing electrical distribution system capable of handling new loads?
  - Contact / work with the applicable Stakeholders in the project:
    - Federal agencies overseeing historic preservation regulations
    - Local preservation commissions
    - Local government
    - Contractors
    - Engineers and Planners
    - Utility company

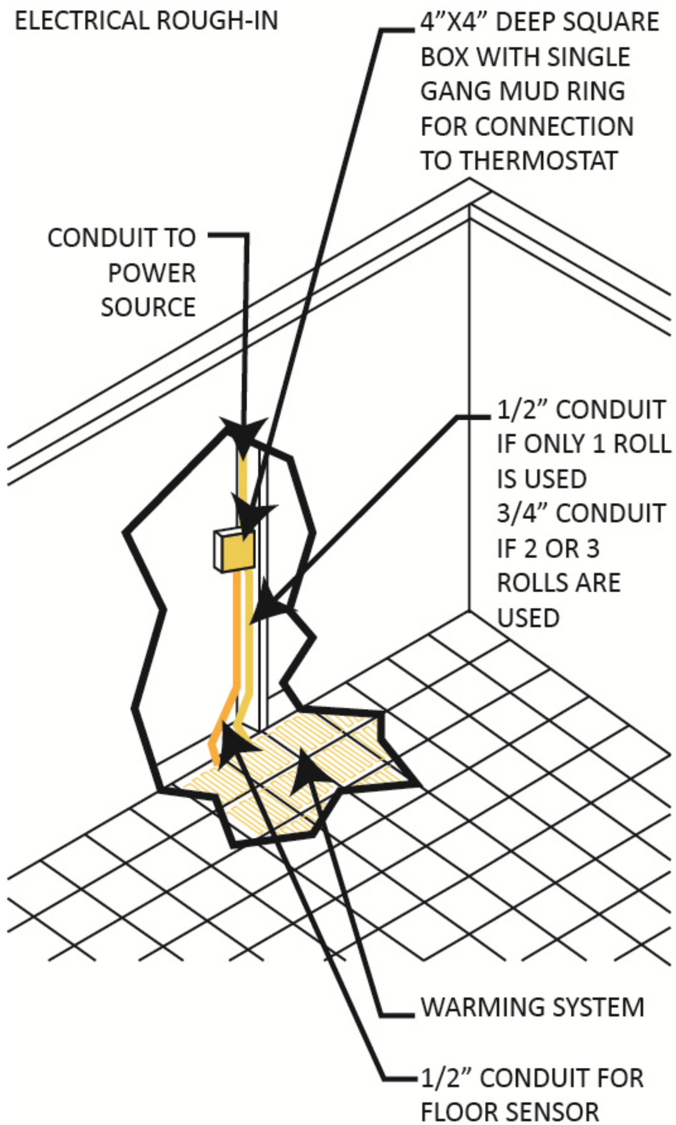


Figure 26 22-1 Electrical rough-in of the system thermostat with connection to the floor system

CONSIDERATIONS FOR INSTALLATION OF RADIANT ELECTRICAL PANELS (PART 2):

- **Approach:** (Energy.gov 2014)
  - **Components:** Electric Radiant heating systems consist of electric cables built into the floors or radiant panels behind walls, or surface mounted to the ceiling. Radiant heaters are controlled from a local in-line voltage thermostat at the baseboard, or from remote line-voltage or low voltage thermostats installed on an interior wall.
    - Electric Radiant heating cables are installed within thick concrete floors to provide a significant thermal mass. This allows for floor heating during off peak electrical rates (9:00p.m. to 6:00 a.m.) to store the heat, and keep the room comfortable for 8-10 hours during the daytime when temperatures are significantly warmer.
    - Radiant heating cables can also be run in the air space beneath the floor. This method is faster and less expensive to install. The cost for heating rises since the air space is heated, making the radiant heating system operate at higher temperatures.
    - Electric Radiant Panels have the quickest response time of any heating technology and are individually controlled for each room. The quick response feature can result in cost and energy savings compared with other systems when rooms are infrequently occupied. The occupant can increase the temperature setting and be comfortable within minutes of entering a room. Radiant heating panels operate on a line-of-sight basis. A user will be most comfortable if they are close to the panel.
    - Secondary Components/Considerations (engineer's responsibility).
      - Verify which walls and/or floors will be demolished to determine the location of the radiant heating panels and/or cables.
      - Coordinate the furniture layouts to insure that radiant wall panels will be located behind furniture.
      - Determine if the existing electrical service is sufficient to handle the additional load based on the area of electric panels required.
      - Controls: Determine the location of the wall mounted thermostats.
      - Thermostat voltage: Line voltage (120 or 240 volts) or low voltage (12 or 24 volts).
      - Circuit Extension: Determine the routing of the conduit and conductors so not to damage the historic character of the interior walls, floor, and ceiling.

Figure 26 22-2 Picture of ceiling mounted electric radiant heating panels.

Figure 26 22-3 Picture showing an electric heating mat with a wall mounted thermostat.

CONSIDERATIONS FOR INSTALLATION OF RADIANT ELECTRICAL PANELS (PART 2) continued:

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:** (Old House Web 2014)
  - Each building and its needs must be evaluated separately. Every effort must be made to protect the historic elements.
  - Special climate needs for historic materials must be evaluated to determine if electric radiant heating can be used.
  - Determining the effect of the installation of the radiant heating system within the facility may require the demolition of existing floors and/or walls. Compare to the cost of the installation of an HVAC or climate control system which may require the addition of new structural elements to support the heaver equipment, the vibration from large equipment and the introduction of moisture in the building.
  - An underfloor radiant heating system could possibly shrink and crack wood flooring.

- **Energy Savings Potential:** (Energy.gov 2014) Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - Electric resistance heating converts nearly 100% of the energy in the electricity to heat. However, most electricity is produced from coal, gas or oil generators that covert only about 30% of the fuel's energy into electricity.
  - Electric radiant heating systems' energy costs are typically less than traditional forced air systems.
  - Electric heat is more expensive than heat produced using combustion appliances, such as natural gas, propane, and oil furnaces.
  - Electric radiant heating may make sense for an addition if it is not practical to extend the existing heating system to supply heat to a new addition.

Figure26 22-4 Electric radiant heating cables being installed in a concrete floor system. SHPO must review and comment on any option that installs a brand new floor.

Figure 26 22-5 Electric heating mats being installed under a wood floor system

CONSIDERATIONS FOR INSTALLATION OF RADIANT ELECTRICAL PANELS (PART 2) continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3.
  - Depending on the type of electric radiant heating system to be installed in a historic building, demolition of existing walls and floors may be required, and will add cost to the upgrade.
  - The installation of electric radiant heating may require an upgrade to the electrical distribution system, incoming utility electric service, and additional electric branch circuit panelboard. The accessibility of running new electrical branch circuiting to the radiant electric panel heater may not be possible due to the face of the historic structure.
  - A Hydronic radiant floor heating system is usually installed as a sole source system.
    - Hydronic radiant floor heating system costs depend on local rates, the number of temperature zones, and the overall size of the system (CostHelper.com 2014).
  - Electric radiant floor heat is typically installed as supplemental heat in one room rather than as the main system for an entire building.
    - Electric radiant floor heating systems typically have a material cost of **$5-$7 / sf**, but including professional installation, costs depend on local rates (CostHelper.com 2014).
    - Electric Radiant cost for a 100 sf room with a 12 watt/sf heating mat that runs 6 hours/day: (Run times differ depending on the area of the country) (HeatTechProducts.com 2013) and (STEP Warmfloor 2012).
      - 100 sf x 12 watt/sf / 1000 (KVA) = 1.2 Kwh x .09 cents/Kwh = .11 cents/hour to run the system. That .11 cents x 6 (hours run in a day) x 183 (total days used in a 6 month period = $120.78 energy cost to heat a 100 sf room.
    - Hydronic radiant floor heating with an electric boiler uses 3.412 kilowatt per hour to equal one BTUh. Most buildings are designed between 20 or 30 BTU/hr/sf; this depends on the area of the country.
      - 1500 sf x 30 BTUh per sf = 45,000 BTUh. Divide the total BTUh by 3.412 Kilowatts, 45,000/3.412 = 13,188.75 (Volt Amps), Divide the total VA by 1000 13,188.75/1000 = 13.2 KVA per hour. Take the 13.2 kva per hour and multiply it by the electric utility. 13.2 KVA x .09 = $1.19 dollars to run the electric boiler per hour. If the boiler runs an average of 6 hrs per day for 30 days, the total monthly cost would be $214.20.

Cost Comparison of the different types of systems		
Radiant Floor Type	**New Construction Cost**	**Heating System**
Hydronic	$6-$16/sf	Sole Source for entire building
Electric	$8-$12/sf	Supplemental heat to one room

Chart 26 22-1

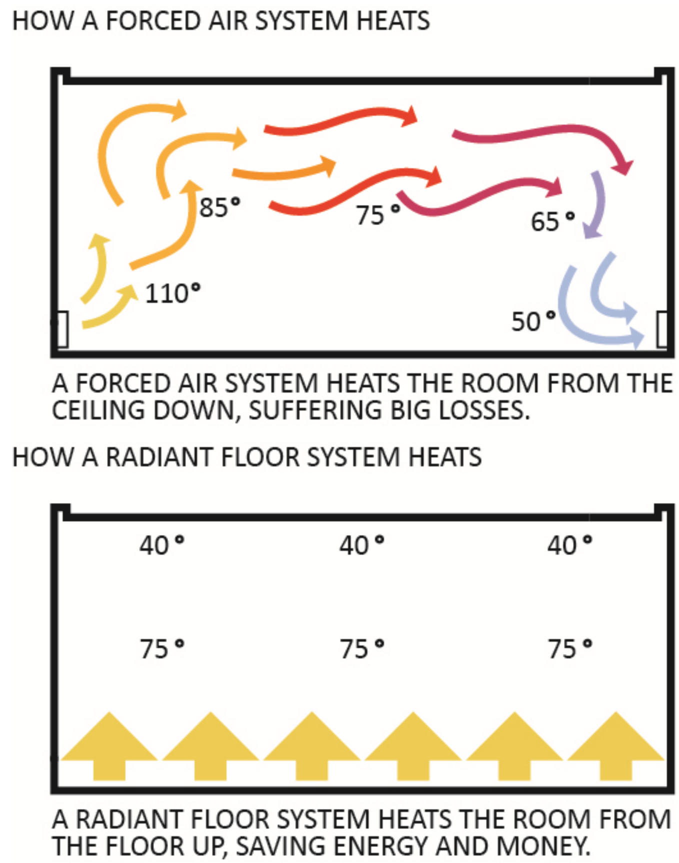


Figure 26 22-6 Diagram comparing the heat distribution between a radiant floor system and forced air system.

CONSIDERATIONS FOR INSTALLATION OF RADIANT ELECTRICAL PANELS (PART 2) continued:

- **Cost Considerations continued:**

Heating System Comparison		Electric Radiant Heating System	Forced Air and Gas Heating System
Efficiency	Efficiency at 100% of capacity	100%	60-90%
	Efficiency at 50% of capacity	100%	30-60%
	Efficient - relative thermal	100%	50-75%
	100% of energy is delivered to the heating element	YES	NO
	Proper sized capacity of "Off Peak" conditions	YES	NO
Maintenance	Annual Maintenance Required - Clean or change filters	NO	YES
	Easy to repair	YES	NO
	Controls - simple and reliable	YES	VARIES
Cost Savings	Expandable - easily and economically	YES	NO
	Compatible with all Floor Coverings	YES	YES
	Floor space required for installation (mechanical room)	NO	YES
	Decorating limitations for furnishings, wall coverings, etc. (no registers, grills, radiators)	NO	YES
	Simple Installation and Operation	YES	NO
	Structural building cost increases required to accommodate	NO	NO
	Venting required to outside and combustion air required	NO	YES
	Concrete required - regular or lightweight	NO	NO
Remodeling	Retrofit-ability in existing concrete or asphalt	YES	NO
	Retrofit into joist space effectively	YES	NO
	Simple modification for remodeling	YES	NO
	Easy and effective for large or small areas	YES	NO
	Minimal floor section height increase (1/8" or less)	YES	YES
Health and Safety	Health & Medical (does not distribute dust, pollen, allergens through the air)	YES	NO
	Environmentally-friendly (greenhouse, glycol, etc.)	YES	NO
	Safety (no high-voltage, no hot surfaces, no combustible gases)	YES	NO

Chart 26 22-2 Chart comparing electric radiant and hydronic heating Systems. From warmzone.com.

GUIDELINE DESCRIPTION: This Guideline will discuss upgrading the lighting system in historic buildings. It will look at how a comprehensive lighting strategy, which includes natural lighting and task lighting considerations, can improve overall energy efficiency. The information provided in this Guideline are suggestions; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 08 02 Natural Lighting
- 08 52 Wood Storm Windows
- 23 08 Selecting HVAC Systems
- 26 01 Solar Photovoltaic Panels

GENERAL NOTES:

- The applicable SOI Standards, Historic Preservation Effects, Energy Savings Potential, and Cost Considerations apply to all installation applications and therefore appear first. The specific applications appear after these topics.
- First, Determine Lighting Goals, aspects to consider:
  - Energy conservation
  - Preservation of historic material and character
  - Occupant comfort
  - Initial cost
  - Operation cost
  - Maintenance requirements
  - Disposal costs and environmental impact.
  - Aesthetics
- Second, Determine the Lighting qualities desired in the building, aspects to consider:
  - Electric lighting supplementing daylight
  - Lighting levels to support tasks and architectural design
  - Lamps temperature range “warm light”
  - Maintaining authenticity
- Change lamps will not affect the UL rating. Recreating fixture will have to be rated by UL or an independent testing lab.

Trends in Recommended Minimum Lighting Levels (in Footcandles)

Category	From Mechanical and Electrical Equipment for Buildings		Illuminating Engineering Society (IES)
	2nd Edition 1945	5th Edition 1971	2011-2012
Offices			
Accounting	30	150	50-100
Regular	20	100	50-100
Conference	10	Not listed	20-70
Corridor/stairs	5	30	20
Schools			
Auditoriums	10	30	10-20
Classrooms	20	70	20-100
Drafting	30-50	100	20-100
Sewing	50-100	150	20-100
Libraries			
Reading Room	20	70	20-100

Chart 26 51-1

See Appendix J for a more complete table of current IES footcandle recommendations.

CONSIDERATIONS:

- **Applicable Secretary of the Interior Standards:**
  - 2: Historic Character Preservation
  - 5: Distinctive Qualities Preservation
  - 9: New Work is compatible with Historic

- **Historic Preservation Effects:**
  - "Identifying ways to reduce energy use, such as installing fixtures and appliances that conserve resources, including energy-efficient lighting or energy-efficient lamps in existing lighting fixtures, sensors and timers that control lighting, before undertaking more invasive treatments that may negatively impact the historic building." (Grimmer, et al. 2011, 2)
  - Retrofitting historic lighting fixtures with appropriate new energy efficient lamps should be considered a priority when considering energy efficiency upgrades to a historic building/structure. (Alderson 2009, 2-4).
  - When upgrading fixtures, the following aspects should be considered (Alderson 2009, 2-4):
    - Changing the lamp should not affect the appearance of the fixture
    - Energy efficient light sources should match the warm to white color range of incandescent light and day light as closely as possible

Color Temperature is the color appearance of a lamp when lit. Higher the temperature (above 4000K) the cooler or more blue the light appears. Lower the temperature the warmer or more orange the light appears. Keep in mind that historic lamps and candles appeared warmer than what current lamps do.

COLOR TEMPERATURE DIAGRAM OF LAMPS

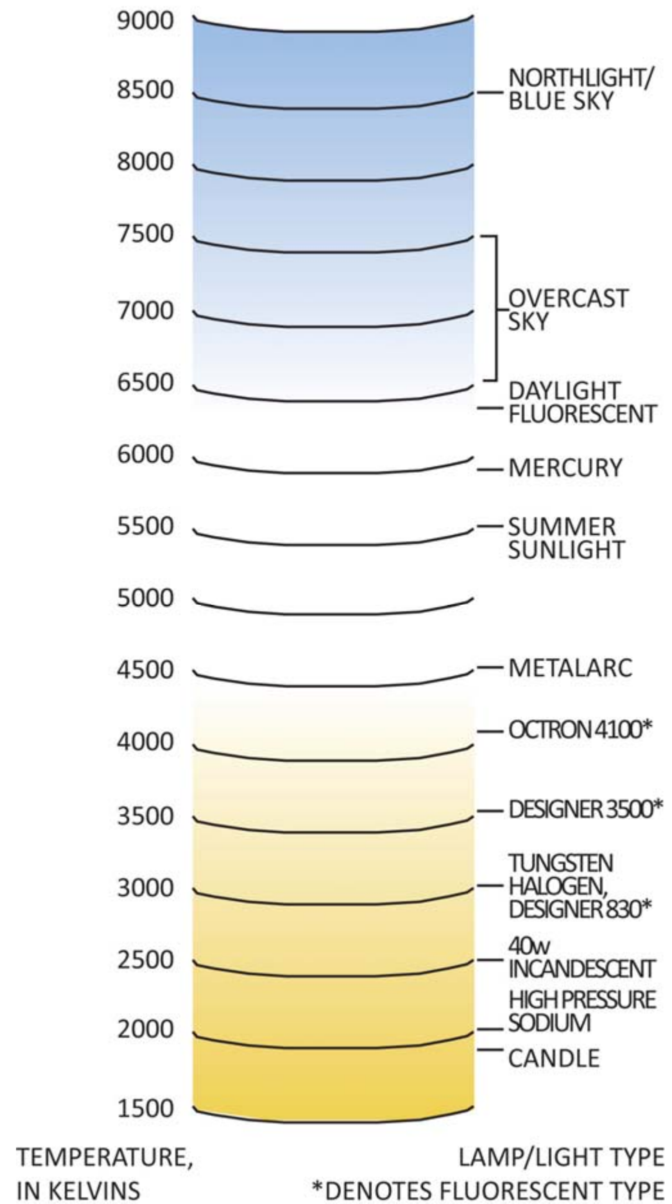


Chart 26 51-2

CONSIDERATIONS continued:

- **Energy Savings Potential and Cost Considerations:**
  - First, determine the Energy cost for Existing lamps, repeat for each type of lamp:
    - Determine number of lamps (light bulbs) ______________
    - Determine wattage (printed on lamp) ______________
    - Determine hours / day used ______________
    - Determine time period 1 month, 30 days
    - Determine cost per kWh? (from utility bill/company) ______________
      - Example uses EIA, US Energy Information Administration for rates.
  - Second, determine the Energy cost for New lamps, repeat for each type of lamp:
    - Determine number of lamps (light bulbs) ______________
    - Determine wattage (printed on lamp) ______________
    - Determine hours/day used ______________
    - Determine time period 1 month, 30 days
    - Determine cost per kWh? (from utility bill/company) ______________
      - Example uses EIA, US Energy Information Administration for rates.
  - CFL use approximately 25% of the energy that an Incandescent uses
  - LED use approximately 13% of the energy that an Incandescent uses

Energy Savings Potential and Cost Consideration Example:

First, determine existing lamp cost (10 -60w Incandescent lamps)

1. *Determine number of lamps = 10*
2. *Determine wattage = 60w*
3. *Determine hours/day used = 10*
4. *Determine time period = 30 days*
5. *Determine cost per kWh = $0.10*
6. *Determine kWh used: 10 x 60 x 10 x 30* ***= 180 kWh***
7. *Determine cost: 180 x .10* ***= $18.00/mon.***

Second, determine new (CFL) lamp cost

8. *Determine number of lamps = 10*
9. *Determine wattage = 15w*
10. *Determine hours/day used = 10*
11. *Determine time period = 30 days*
12. *Determine cost per kWh = $0.10*
13. *Determine kWh used: 10 x 15 x 10 x 30* ***= 45 kWh***
14. *Determine cost: 45 x .10* ***= $4.50/mon.***

Third, repeat for LED lamp cost (10– 8w lamps)

15. *Determine kWh used: 10 x 8 x 10 x 30* ***= 24 kWh***
16. *Determine cost: 24 x .10* ***= $2.40/mon.***

CONSIDERATIONS continued:

- **Energy Savings Potential and Cost Considerations continued:**

Cost Comparison between Incandescent, CFL and LED Lamps

Lamps	Watts	Lumens	Lumens/Watts	Price/ lamps	Lamp Lifespan	Lamps needed for 50K hrs	50k hours lamp expense
Incandescent	60	800	13.3	$1.25	1,200 hrs	42	$52.50
CFL	15	900	60	$3.95	10,000 hrs	5	$19.75
LED	8	800	100	$35.95	50,000 hrs	1	$35.95

Lamps	50k hours lamp expense	50k hours Energy expense	Total Cost per for 50k hr
Incandescent	$52.50	$298.80	$351.30
CFL	$19.75	$74.70	$94.45
LED	$35.95	$39.84	$75.79

Chart 26 51-3

Notes:

1. Lamp costs are the average cost of lamps in the Albuquerque, NM area 2012
2. 50k of Energy expense is based on LED lamp life
3. Typically, color is the first consideration in lighting design, followed by availability.

CONSIDERATIONS FOR UPGRADING INTERIOR HISTORIC FIXTURES:

- **Approach:**
    - Removal of existing historic lighting fixtures for Restoration
        - Determine the type of lamps to be used: LED's or CFL's
        - Replacement of old yellow lens
        - Replacement of reflectors
        - Rewire fixtures
    - Retrofitting existing fixtures with new lamps to meet current performance /energy goals
        - **Light Emitting Diodes (LED's)**
            - Benefits:
                - Average Lamp life of 50,000 hours
                - Lamp temperature range
                - Low energy usage
                - Easy to retrofit in fixtures
            - Disadvantage: Initial cost is higher compared to CFL's and incandescent lamps
        - **Compact Fluorescents lamps(CFL's)**
            - Benefits
                - Longer lamp life than the incandescent lamp
                - Low energy usage then an incandescent lamp
            - Disadvantages
                - Initial cost is higher compared to incandescent lamps
                - Provides a whiter light, not suitable for high lighting art and/or objects
                - Higher energy usage then a LED
        - **Electronic ballast**
            - Benefits: Lower energy usage and longer life than magnetic ballast.
            - Disadvantage: Initial cost is higher than a magnetic ballast
        - **Dimming ballast**
            - Benefits: Lower energy usage and longer life than magnetic ballast.
                - Can control the lighting levels in CFL's lamps
                - Will reduce energy usage by reducing the lighting levels
            - Disadvantage: Initial cost is higher than a standard electronic ballast

Figure 26 51-1 CFL's come in various shapes and sizes

Figure 26 51-2 LED's also come in various shapes and sizes to fit the lighting need.

CONSIDERATIONS FOR UPGRADING INTERIOR HISTORIC FIXTURES:

- **Approach continued:**
  - Identify locations where historic fixtures have been removed that should be replaced
  - Replacement or relocation of historic fixture.
    - Take historic fixtures from back room areas and relocate them to public areas
  - Consider having historic fixtures recreated
    - Would provide new technology lamps and ballast in a historic looking fixture
    - UL labeling or the equivalent testing of can be provided by testing labs
    - Provide with remote ballast as needed
    - Cost consideration
  - Determine Lamp controllability required / desired: well controlled lighting systems reduce energy use, since the possibility of leaving lights on when they are not used is reduced.
    - Time Clocks
    - Photo Cells
    - Motion Sensors
    - Replace wiring between fixtures and switches
    - Extend new wiring to branch circuit panel
  - Coordinate with Daylighting strategies (08 02 Natural Lighting)
  - Determine required / desired Lighting Levels
    - Recalculate the foot candle levels in all area
    - Levels shall be based on new energy code and IES standards
    - This may allow for the distribution of historic fixtures to other locations within the facility without effecting new lighting level standards

Figure 26 51-3 Old Terminal, Albuquerque, New Mexico The historic fixtures were found in local museum but were not reinstalled because obtaining the UL rating was time consuming and prohibitively expensive. Therefore, the historic fixtures were replicated and can be seen in the above photograph.

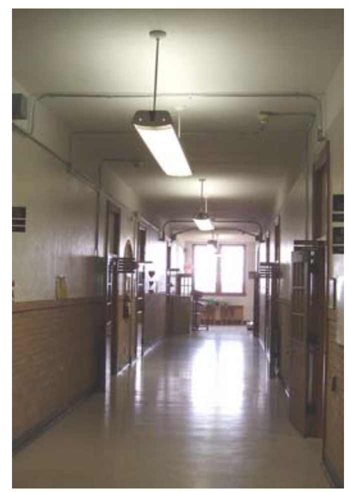


Figure 26 51-4
Before Renovation

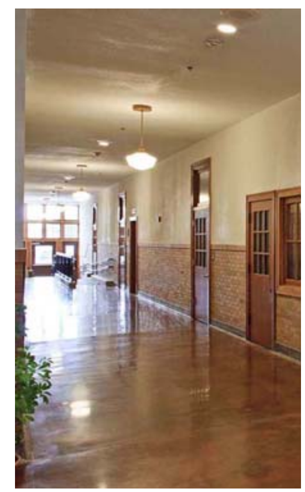


Figure 26 51-5
After Renovation

The Renovation restored lighting back to similar levels and type fixtures. Coronado School, Albuquerque, NM

CONSIDERATIONS FOR UPGRADING EXTERIOR HISTORIC FIXTURES:

- **Approach:**
  - Restoration of existing fixtures
    - Provide with new technology lamps (see page 150 for more information on the LED and CFL lamp types listed below)
      - Light Emitting Diodes (LED's)
      - Compact Fluorescents lamps (CFL's)
      - High Intensity discharged lamps (HID)
        - Benefits
          - Long lamp life
          - Can provide higher lumen output than LED's and CFL's.
          - Requires fewer fixtures than LED's or CFL's to provide the same levels.
          - Good for indirect lighting needs
        - Disadvantages
          - **High Energy use, but few fixtures might still make this feasible**
          - High lamp and ballast cost
      - Rewire fixtures
  - Identify locations where historic fixtures have been removed and should be replaced
  - Replacement or relocation of historic fixture.
    - Take historic fixtures from back of buildings or from areas not normally seen by the public and relocate them to public areas
  - Use of new fixtures to supplement existing historic lighting fixtures.
    - Install new lighting in non-intrusive areas to highlight features of a building
    - Use accent lighting on architectural features
    - Landscape lighting
  - Have historic fixture recreated to match existing fixtures
    - Provide with new technology lamps.
    - Provide with remote ballast as needed
  - Lamp controllability: especially on the exterior, more control equals less energy use
    - Time Clocks
    - Photo Cells

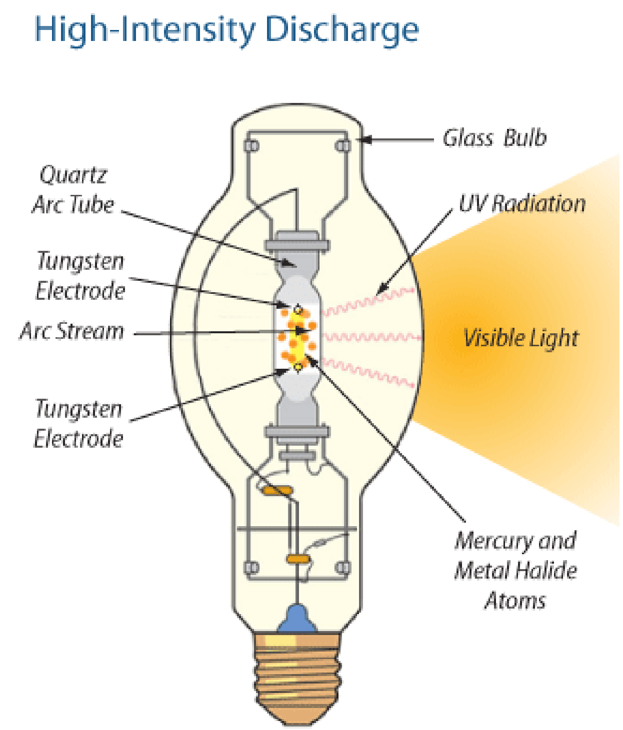


Figure 26 51-6
Graphic courtesy of the US Department of Energy

CONSIDERATIONS FOR SUPPLEMENTAL LIGHTING:

- **Approach:**
  - Supplemental lighting (U.S. General Services Administration 2012)
    - Is to provide increasing lighting levels in areas where the historic lighting fixtures cannot provide sufficient lighting levels
    - Should avoid competing visually with historic lighting
    - Free standing torchieres, task lighting and discrete accent lighting are recommended for increasing lighting levels.
    - Special care should be taken in ceremonial spaces containing ornamental ceiling and historic chandeliers.
  - Discretely placed new lighting fixtures to avoid competing with historic lighting.
    - Cove Lighting
    - Indirect Lighting
    - Cornice Lighting
    - Additional Task Lighting
  - Lamp controllability
    - Dimmable lamps
    - Day light sensors to control lamp intensity
    - Motion sensors
  - Conduit routing
    - Keep conduit exposure to a minimum
    - Do not run conduit or wiring exposed in public areas
    - Conceal with conduit system along baseboard or behind millwork
    - Do not drill into existing ornamental finishes. If unavoidable, drill in corners to minimize impact.
    - Channel walls to provide minimal damage to existing walls
    - Avoid altering decorated character-defining features

GUIDELINE DESCRIPTION: This Guideline will examine historic landscape materials and features that have contributed to energy conservation in the past. These landscape materials and features should be retained even if they are not considered character defining features because they do help conserve energy. The features to be discussed include paving materials and vegetative ground covers, patios and courtyards, fountains, and shade structures. The information provided in this Guideline are ideas; it is up to the Design Team to ensure that the specific implementation meet UFC requirements.

RELATED GUIDELINES:

- 00 03 Major Preservation and Energy Issues
- 02 01 Preservation of Historical Energy Related Measures and Devices
- 32 29 Preservation of Historic Plant Materials for Shading and Wind Reduction

GENERAL NOTES:

- Historically, people used protected, well designed, outdoor spaces more frequently than we do today. However, such outdoor spaces are starting to be more appreciated, now, especially for break areas and lunch spaces. In good weather, such spaces are even used for informal meetings and discussions.
- On all historic energy saving landscape features, determine with the CRM/SHPO, early in the process, which ones are to be considered character defining features to be preserved. Landscape features are often part of the Cultural Landscape.
- Historic landscape features are often not recognized as energy savers, and are sometimes destroyed to make room for new needs such as parking. Courtyards are occasionally enclosed to gain more usable space. When they are destroyed or replaced, there is an energy premium to be paid.
- Because of the wide variety of historic landscape energy saving features, and because their size and character are an important factor in determining their energy profile, it is not possible to calculate their dollar value as with other Guidelines. This Guideline intends to educate the decision makers that historic landscape features are important and should not be replaced with the assumption that there are no energy consequences.
- Landscaped courtyards and shade structures reduce the “heat island effect.”

Figure 32 17-1 Covered portico at Special Collections Library, Albuquerque, NM.

Figure 32 17-2 Covered portico, St. John’s College, NM

Figure 32 17-3 Crusher fine ground covering

GENERAL NOTES continued:

- Paving materials that allow for water to penetrate, or that avoid reflecting heat into a building can help cool the area around a building in summer.

CONSIDERATIONS FOR PAVING MATERIALS:

- **Approach:**
    - o Sunlight striking dark pavement is readily absorbed and re-radiates heat into the air above the pavement. There is a lag between the time the sun's energy is absorbed and when it is re-radiated. This re-radiation is a benefit to adjacent buildings in the winter, but not in the summer.
    - o Light colored pavement absorbs less and reflects more energy onto adjacent surfaces. This reflection is immediate. This reflection is a benefit to adjacent buildings in the winter, but not in the summer.
    - o In dry climates, nighttime temperatures are much lower than daytime temperatures. Here, a darker pavement can re-radiate heat later without over heating the air around it.
    - o In wet climates, temperatures may be steady for the full 24-hour day. In winter, reflected or re-radiated heat is a benefit to adjacent building. In summer, paving should be shaded to reduce heating of the adjacent building.
    - o Where re-radiated or reflected solar energy is not desirable, the addition of new shade trees or a shade structure can be discussed with the CRM/SHPO. If the re-radiation is desirable in winter, but not in summer, a deciduous shade tree or a demountable shade structure is recommended.
    - o The consistency of the contact of the pavers to the ground below can affect the amount of heat that is transferred to the ground. The more readily that heat from pavers can travel into the ground, the longer it will take for that heat to radiate back into the air.

- **Applicable Secretary of the Interior Standards:**
    - o 3: Avoid False Historic Changes
    - o 5: Distinctive Qualities Preservation

Figure 32 17-4 Permeable Pavers, crusher fines fill joints.

Figure 32 17-5 Dark brick pavers set in sand allow for permeability of water, but absorb and reflect heat from the sun.

CONSIDERATIONS FOR PAVING MATERIALS continued:

- **Historic Preservation Effects:**
  - Paving materials may be features in a Cultural Landscape. They may be considered a character defining feature of the landscape, as well as affecting adjacent buildings from an energy standpoint.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses. As noted in the Guideline Description, the nature of the topics of this Guideline does not lend itself to reliable calculations of energy savings for retaining historic landscape features or energy increases caused by removal of these features.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Energy costs related to removal, replacement, or shading of pavement or pavers cannot be determined in any reliable way. While the costs of removal, replacement, new shade trees, etc. can be estimated, there is no energy cost available to compare with that expenditure.
  - The intention here is to develop awareness that these landscape features have an energy saving component to be considered.

Figure 32 17-6

Figure 32 17-7

CONSIDERATIONS FOR VEGETATIVE GROUND COVERS:

- **Approach:**
  - Vegetative ground covers (grass and other species) absorb the sun's energy and convert it to food, not heat. Therefore, they do not reflect nor re-radiate heat to an adjacent building wall. This characteristic is an advantage in summer; not in winter.
  - Vegetative ground covers require maintenance and water. Amounts depend upon the species, the soil conditions, and the climate of the site.
  - Water applied to landscaping uses energy either for pumping from a well, or for treatment and pumping from a public water supply.
  - In many parts of the country, water is in increasingly short supply. Where historic landscapes included lawns and other vegetative ground covers, SHPO recommended redesigns of the landscapes to conserve water have been used. Water use reduction saves energy.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - In the West, many historic sites are struggling to retain grassed lawns and other water consumptive landscape features in the face of drought and the need for responsible stewardship of natural resources. Water use does require energy and impacts utility budgets as well.
  - Where water is not in short supply, and historic ground covers can be maintained, there is no negative impact to the historic fabric.

Figure 32 17-8 Before

Figure 32 17-9 After

At the Bureau of Reclamation Administration Building in Boulder City, Nevada, the historic landscape was designed with extensive lawns. The message of the design was that Boulder Dam would make the desert bloom.

Today this historic landscape is being revised to deal with the realities of drought in the West. The lower portion of the hillside remains a lawn. In the upper portion of the landscape, sod has been removed and replaced with drought tolerant plants. Specimen, historic trees are retained.

CONSIDERATIONS FOR VEGETATIVE GROUND COVERS:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
  - Grass and other vegetative ground covers do not reflect sunlight to any significant degree. Therefore, having a ground cover adjacent to a building will not contribute to heating the building's wall.
  - In SHPO recommended ground cover redesigns to save water, partial replacement of the grass is accomplished by installing drought tolerant plants surrounded by gravel. Light colored gravel will reflect heat to adjacent building walls, which is welcomed in winter, but not in summer. Dark colored gravel absorbs more heat and re-radiates some of it in cooler evenings. Dark colored gravel may not be as aesthetically appropriate as light colored gravel.
  - Measurement of the energy savings for cooling due to historic vegetative ground cover is so varied that no reliable measurement can be included in this Guideline.
  - When vegetative ground cover is replaced with gravel near a building, solar heat can be reflected onto the wall. Lighter colored gravel will reflect more heat.
  - Reducing water use will reduce the energy associated with pumping and treating water.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Energy costs related to the redesign of historic vegetative landscapes cannot be determined in any reliable way because they are so site specific. In addition, there is no way to quantify the energy costs of the existing landscape; so, there is no baseline to compare future energy uses. The intention here is to development awareness that these landscape features have an energy saving component to be considered.

Figure 32 17-10 Before: Special Collections Library, Albuquerque, NM. Historic landscaping consisted of large areas of blue grass ornamented with sections of juniper shrubs.

Figure 32 17-11 After: Special Collections Library, Albuquerque, NM. Renovated landscaping maintained the historic character by providing a lawn of desert grass near the pedestrian walks, but added in large areas filled with crusher fines. Juniper shrubs were changed out for other xeric plants and shrubs.

CONSIDERATIONS FOR PATIOS AND COURTYARDS:

- **Approach:**
  - Courtyards are a feature of larger historic buildings where natural lighting was needed in many spaces. The interior spaces tended to be narrow so that all spaces would be reached by the sunlight.
  - Smaller buildings would have courtyards or patios for the same reason; often the buildings were "U" shaped.
  - The material on the ground plane of the patio impacts the energy performance of the building. Vegetative ground covers add to cooling of the building by evaporating water and thereby cooling the air in the courtyard. Dark paving adds to the heating of the building by absorbing sun and later re-radiating that heat. Light pavers can heat the building by reflecting the sun's heat onto the walls and through the windows.
  - Deciduous shade trees in a courtyard can serve to reduce the heating of paving of any color in a courtyard by shading the surfaces.
  - The terms "Patio" and "Courtyard" can be used similarly. However, patios are generally considered smaller spaces.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation

- **Historic Preservation Effects:**
  - Sometimes, operations in need of additional space are tempted to enclose courtyards. The rationale is that four walls are already built, and therefore the additional space is less expensive to use than building an addition would be. This type of change should be avoided for the following reasons:
    - The Courtyard is likely a character defining feature of the historic structure, and as such should be protected.
    - The enclosing of a courtyard will reduce the natural light entering the adjacent spaces and increase the energy use from artificial lighting.

Figure 32 17-12

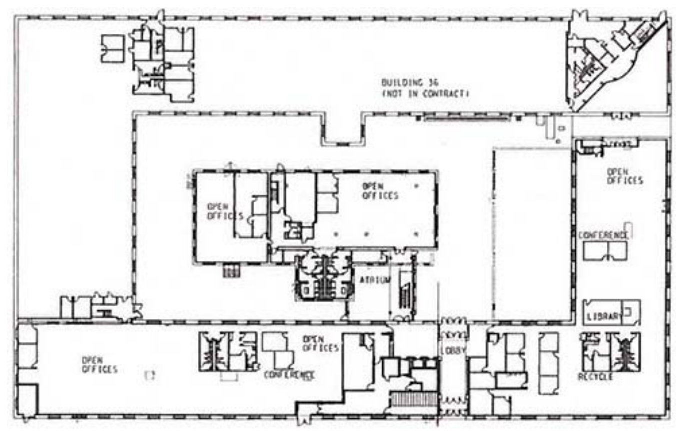


Figure 32 17-13

At the Washington Navy Yards, Building 33, a new space was added in a relatively large courtyard. It was added in such a way that natural lighting to interior spaces was not reduced. In the photo, the new addition is to the right.

CONSIDERATIONS FOR PATIOS AND COURTYARDS:

- **Historic Preservation Effects continued:**
    - If enclosing a courtyard includes complete removal of the original windows, there are other concerns such as:
        - Removal of historic windows is specifically discouraged by the NPS.
        - Reduced suitability of the work space.
        - Code requirements for windows for certain types of occupancies may also be violated.
    - Assuming the courtyard is a character defining feature, there should be a minimum of changes to the shape of the space, building, and plant materials.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts**.**
    - As with other features in historic buildings, courtyards are already saving energy. Determining the quantity of energy they are saving is difficult since that calculation would involve determining the energy used by alternative configurations, which are numerous. One simple way to determine part of this energy savings would be to calculate the cost of artificially lighting all the spaces adjacent to the courtyard.
    - This Guideline is intended to encourage the retention of these features, not only for their energy saving characteristics, but also for their aesthetic and historical value.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
    - Energy savings related to changes to courtyards cannot be determined in any reliable way because they are so site specific.
    - The heat transfer through the walls of the courtyard is a factor. These walls can receive additional insulation (see Guidelines involving insulation of various walls – Guidelines 03 31, 04 21, 05 51, 06 81, and 07 21). The cost benefits of increased insulation can be examined using information in those sections.
    - If changes to the courtyard are likely to be recommended by the SHPO, the design architects/engineers should be asked to perform a cost /benefit analysis of the proposed solution. It must include the cost of increasing the artificial lighting to take the place of any reduction of natural lighting caused by the change.

Figure 32 17-14

Figure 32 17-15

Courtyards, like those pictured above, allow interior spaces the benefits of natural lighting and ventilation. Additionally, such courtyards are beneficial to the users of the buildings by providing protected outdoor space.

CONSIDERATIONS FOR FOUNTAINS:

- **Approach:**
  - The use of fountains as cooling features in courtyards dates back to Moorish architecture in Spain. Their use in the USA has concentrated in southern states, especially those in the Southwest.
  - Fountains cool a space by acting as evaporative air coolers. As the water evaporates, the water molecules absorb heat as the liquid water turns to vapor.
  - Fountains create a very positive ambience, visually and acoustically.
  - Fountains require maintenance to keep them clean and functioning properly.
  - Some consider fountains a hazard or an attractive nuisance where children are present.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Historic fountains will probably be considered character defining features of a historic building or landscape. Therefore, they should be maintained.
  - Through the years, some fountains are converted to planters because the maintenance of a fountain takes more effort than the maintenance of a planter.
  - Early discussions with the SHPO can determine the appropriate future use of the fountain. If changes to the fountain such as conversion to a planter are considered, they should be reviewed with the SHPO.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses to understand the limitations and key concepts.
  - It is very difficult to determine in a useful way the energy savings of an existing fountain.
  - The fountain pump(s) requires some energy to operate. Energy use of a pump depends upon the size of the fountain, and the amount of water pumped.
  - The amount of cooling provided by the evaporation of the water depends upon the size and the air movement patterns of the courtyard.

Figure 32 17-16 Alhambra, Granada, Spain. This site is known for its many courtyards and water features.

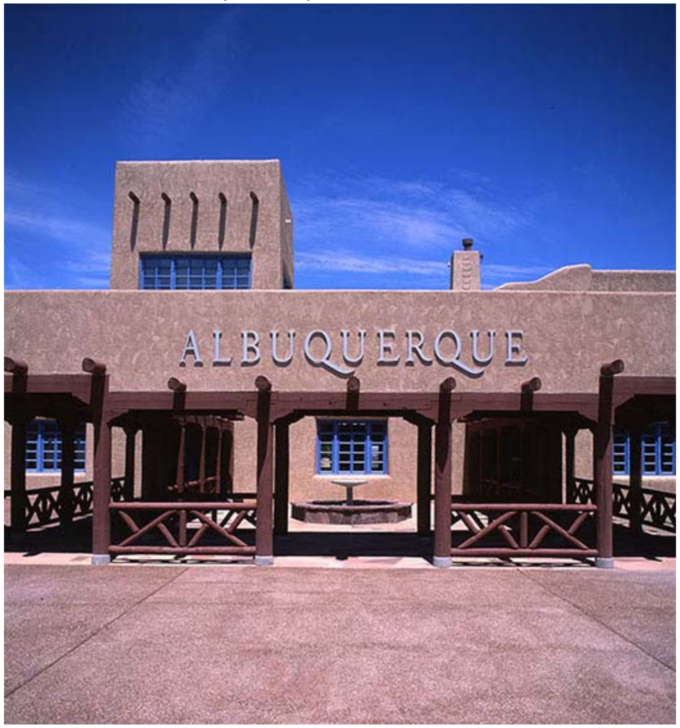


Figure 32 17-17 Refurbished fountain in courtyard at the Old Terminal Building, Albuquerque, NM.

CONSIDERATIONS FOR FOUNTAINS continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - Cost savings related to changes to historic fountains cannot be determined in any reliable way because they are so site specific.
  - The cooling effect and resulting cost savings are dependent on the humidity and temperature in the immediate area.
  - There is no easy-to-use base line information regarding the cooling effect of an existing fountain to compare with the loss of that cooling were the fountain removed, turned into a planter, or otherwise decommissioned.

Figure 32 17-18 Capilla de las Capuchinas, Tlalpan, Mexico City, Mexico, courtyard with fountain.

CONSIDERATIONS FOR SHADE STRUCTURES:

- **Approach:**
  - Prior to the advent of air conditioning, in hot climates, many residential and institutional facilities made use of shade structures. These structures allowed for meeting and working (to some extent) out of doors when the interiors of buildings were uncomfortably hot.
  - In hot, dry climates shaded outdoor structures allowed for the breeze to cool users of the structure. Shaded areas in hot humid climates were not as comfortable in the summer, but they were occasionally preferable to a hot, humid interior with less cross ventilation.
  - Types of shade structures include porches attached to major structures and freestanding structures on the grounds or in courtyards.
  - Plantings often grow on shade structures and add to the shading effect. The moisture in the plants may also evaporate, thereby cooling the surrounding air.
  - Porches not only provide shade to the occupants, but they shade the building wall so that the solar heat gain does not penetrate into the building.
  - Due to the wide variety of structure sizes, adjacent ground conditions, climatic conditions, and structural materials, it is not useful to attempt to establish a generic process for determining a base line of energy conservation for a historic shade structure. The intention here is to make readers aware that such structures are important from an architectural and historical perspective, and that they do provide an energy efficient “oasis.”

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

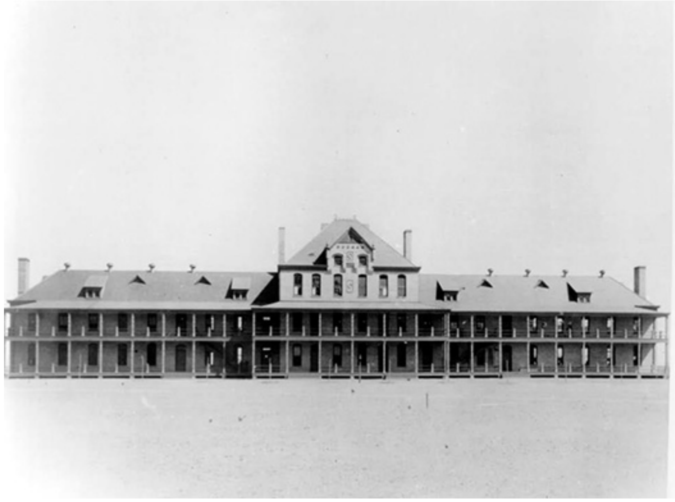


Figure 32 17-19
Building #13 at Ft. Bliss, El Paso, TX, built in 1893 as a barracks had extensive porches on the west facade to shade the building. It is used to day as an office building.

Figure 32 17-20 Stand-alone gazebo.

CONSIDERATIONS FOR SHADE STRUCTURES continued:

- **Historic Preservation Effects:**
  - Prior to proposals to remove or alter shade structures, confer with the SHPO to determine if the structure is a character defining feature of the cultural landscape associated with the nearby historic structure(s).
  - Porches are very likely to be considered character defining features of the historic building, while free-standing shade structures may be considered character defining features of the historic cultural landscape.
  - These features, usually constructed without walls to support them laterally, are often fragile compared to buildings. The addition of supporting elements must be carefully done, so as not to change the design significantly. New, unobtrusive supports may be required.

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses.
  - As noted earlier, shade structures vary so widely in their characteristics and site conditions that there are no useful rules of thumb to measure their energy savings potential. There are also, usually, no means to determine the base line energy use or savings of these structures. The basic principal is known to all of us who are aware that standing in the shade is preferable to standing in the sun on a hot day. The effect of these historic structures is well known if the quantification is not.

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - As Energy Savings Potential is not knowable in a quantitative sense, neither are the Cost Considerations resulting by maintaining a historic shade structure. The purpose of this Guideline is to make the reader aware that these structures are an important part of the historic fabric of a site and also serve as useful cooling energy savers.

Figure 32 17-21 Shade structure added at historic building.

Resources:

U.S. Department of Defense, **"DENIX - Cultural Resources, Historic Buildings and Structures, Inventories and Evaluation."**

Inventory of Cultural Resources for DoD: National Trust for Historic Preservation, **"Reusing America's Historic National Guard Armories."**

GUIDELINE DESCRIPTION: This Guideline will examine the use of historic landscape materials for energy use reduction. It will examine the use of landscaping (plant materials and berms) for wind control, reducing unwanted heat transfer from a building through infiltration. It will also examine the use of trees for shading and solar access. Unwanted solar access can cause a building to overheat. This Guideline will discuss how and why these measures were used historically and will provide considerations regarding their protection during construction, continued use, modification, and preservation.

Determining Energy Savings Potential and Cost Considerations for this Guideline is a different situation than in the other Guidelines that propose improvements to the historic building itself. With these features we are making a case for retention of an existing historic energy saving feature, such as a windbreak of trees. Because the circumstances and sites of these features vary so widely, we will address cost only in general terms. The intention of this Guideline is to instruct the reader that, while not readily quantified, these features do save energy and should be retained.

The information provided in this Guideline are ideas; it is up to the Design Team to ensure that the specific implementation meets UFC requirements.

RELATED GUIDELINES:

- 00 02 Working with State Historic Preservation Officer (SHPO)
- 08 41 Reducing Air Transfer at Historic Doors/Entrances
- 32 17 Preservation of Historic Landscape Materials and Fixtures

GENERAL NOTES:

- Some of the items discussed in this Guideline are measures or devices that were used to enhance thermal comfort historically and required no energy to operate.
- On all historic energy saving landscape features, determine with the CRM/SHPO, early in the process, which ones are to be considered character defining features of a cultural landscape to be preserved.

Figure 32 29-1 Evergreen Windbreak, Lawrence County, PA, age unknown.

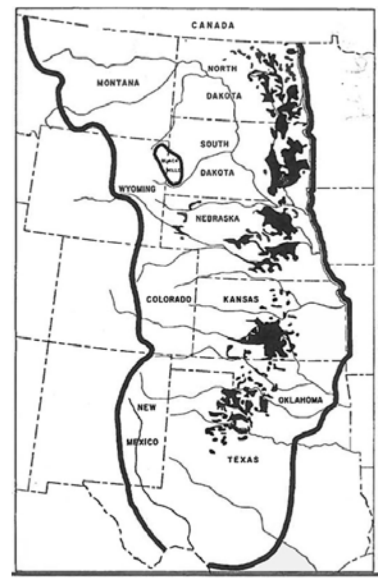


Figure 32 29-2 From 1935-1942, the Prairie States Forestry Project planted 18,600 miles of shelterbelts using about 217 million trees. Source: Bruce Wright, National Forester, USDA Natural Resources Conservation Service.

GENERAL NOTES continued:

- Energy related features that are determined to be character defining features must be protected during construction.
- Historic landscape features are often not recognized as energy savers, and are sometimes destroyed to make room for new needs such as parking. If users realize that such features can continue to serve as energy savers, more historic fabric can be preserved.

CONSIDERATIONS FOR HISTORIC WIND BREAKS:

- **Approach:**
  - A windbreak, also called a shelterbelt, is a row of close-knit trees or shrubs placed to provide protection from winds. They were popularized during the New Deal era, and continue to be common in windy areas.
  - For the purpose of this Guideline we will examine wind breaks placed near a structure. Most often these trees will be evergreens, anticipating high winds all year long.
  - The primary use was to protect agricultural fields and livestock, but their effectiveness was soon adopted by building owners and users.
  - Wind speed causes infiltration in buildings. Windbreaks reduce wind speed in their wake and, therefore, reduce infiltration in buildings in their wind shadow.
  - In addition to reducing the loss of heat due to infiltration, windbreaks can reduce dust infiltration, provide a living snow fence, and reduce sound transfer from a busy street.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Historic wind breaks are elements in a Cultural Landscape. They may be considered a character defining feature of the landscape, as well as a wind speed reducer that saves building energy. Retention is recommended.

Open Wind Speed 20 mph
Deciduous 25-35% Density

H distance from windbreak	5H	10H	15H	20H	30H
miles per hour	10	13	16	17	20
% of open wind speed	50%	65%	80%	85%	100%

Open Wind Speed 20 mph
Conifer 40-60% Density

H distance from windbreak	5H	10H	15H	20H	30H
miles per hour	6	10	12	15	19
% of open wind speed	30%	50%	60%	75%	95%

Open Wind Speed 20 mph
Multi Row 60-80% Density

H distance from windbreak	5H	10H	15H	20H	30H
miles per hour	5	7	13	17	19
% of open wind speed	25%	35%	65%	85%	95%

Open Wind Speed 20 mph
Solid Fence 100% Density

H distance from windbreak	5H	10H	15H	20H	30H
miles per hour	5	14	18	19	20
% of open wind speed	25%	70%	90%	95%	100%

Figure 2. Wind speed reductions to the lee of windbreaks with different densities. A) density of 25-35%, B) density of 40-60%, C) density of 60-80%, D) density of 100%.

Figure 32 29-3

CONSIDERATIONS FOR HISTORIC WIND BREAKS continued:

- **Historic Preservation Effects continued:**
  - If a historic wind break is in place, it should be retained. If the installation of a new windbreak is convenient from a site planning point of view, and agreeable to the CRM/SHPO, it can be installed to reduce energy costs of a leeward building.
  - If historic wind breaks are in need of renovation see: http://nac.unl.edu/multimedia/conferences/Great_Plains/windbreakrenovation20120724.htm

- **Energy Savings Potential:**
  - The energy conservation effectiveness of a wind break depends on the height and density of the trees and their distance from the structure.
  - A wind break can reduce heating costs by reducing the wind chill factor. For example, if the outside temperature is 10 degrees F and the wind speed is 20 miles per hour, the wind chill factor is -24 degrees F. When the wind is slowed by the wind break, the wind chill factor is not as severe, thereby reducing the heating load on the building. (Energy.gov, "Landscape Windbreaks and Efficiency," 2012).
  - "Research conducted on the Great Plains has shown that up to 25 percent energy savings for heating is possible from windbreaks." An evergreen, properly placed, can divert cold winds away from a building.
  - The effective distance from the structure depends on the tree height. The optimum distance for reducing wind velocity is about one to three times tree height. However, a windbreak can provide reasonable protection at a distance of six times tree height. (USDA National Agroforestry Center, "Agroforestry: Working Trees for Agriculture," 2012).
  - Living snow fences, such as low growing wind breaks positioned up wind of a road can reduce the need for snow removal, thus saving fuel.
  - A study in South Dakota found that windbreaks to the north, west, and east of houses cut winter fuel consumption by an average of 40%. (U.S. Department of Energy, "Landscaping for Energy Efficiency," 1995).

Resources:

All SHPO:
http://www.nps.gov/nr/shpolist.htm

SHPO Inventories of Historic Places on the Web
http://www.nps.gov/nr/shpoinventories.htm

National Park Service provides additional useful links:
http://www.nps.gov/nr/preservation_links.htm

Windbreak Basics:
http://nac.unl.edu/windbreaks.htm

Department of Defense Legacy Management Program:
http://denix.osd.mil/cr/upload/07-382_FINAL.pdf, **Chapter 6, Design Guidelines-Site and Setting, Section 6.3 Landscapes and Features.**

Colorado State University Extension Program:
Walker and Newman, *Landscaping for Energy Conservation,* (2009), http://www.ext.colostate.edu/pubs/garden/07225.pdf.

CONSIDERATIONS FOR HISTORIC WIND BREAKS continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses.
    - As Energy Savings Potential is not knowable in a quantitative sense, neither are the Cost Considerations resulting by maintaining a wind break. The purpose of this Guideline is to make the reader aware that these features are an important part of the historic fabric of a site and also serve as useful energy savers.
    - Potential savings can be developed using infiltration data. These are savings already in place if the windbreak is existing. Removal of the windbreak will increase energy costs. The quantity of increase is difficult to predict because it depends on the specific circumstances. The Energy Savings Potential section above can suggest saving predictions.
    - Calculating the savings for this Guideline may only be related to the energy saving if the following approaches are taken:
        - Have to assume tree location and density of trees at maturity.

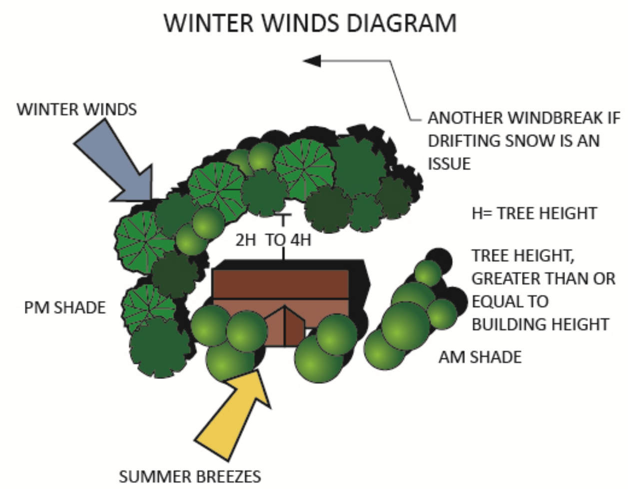


Figure 32 29-4

Figure 32 29-5 Windbreaks can reduce heating costs. Photo courtesy of Lynn Betts, USDA Natural Resources Conservation Service.

CONSIDERATIONS FOR HISTORIC WINDWARD BERMS:

- **Approach:**
  - A windward berm is a linear mound of earth, usually grassed, that deflects wind from a building.
  - For the purpose of this Guideline we will examine windward berms placed near a structure. These wind protectors behave much like wind breaks made of trees, but they are solid and therefore deflect the wind more completely.
  - The primary use was to protect agricultural fields and livestock, but their effectiveness was soon adopted by building owners, and they were even used at residential buildings.
  - Windward berms were never as popular as wind breaks because they are more trouble to build, they cannot be walked through, and if grassed, they are difficult to mow. Also, windward berms cannot realistically be built as high as trees can grow. They do block the wind more effectively than trees for a given height because of their solidity.
  - In addition to reducing the loss of heat due to infiltration, windward berms can reduce dust infiltration, provide a living snow fence, and reduce sound transfer from a busy street.
  - If a windward berm is in place, it should be retained. If the installation of a new windward berm is convenient from a site planning point of view, it can be installed to reduce energy costs of a leeward building.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Historic windward berms are elements in a Cultural Landscape. They may be considered a character defining feature of the landscape, as well as a wind speed reducer that saves building energy.
  - If a historic windward berm is in place, it should be retained. If the installation of a new berm is convenient from a site planning point of view, and agreeable to the CRM/SHPO, it can be installed to reduce energy costs of a leeward building.

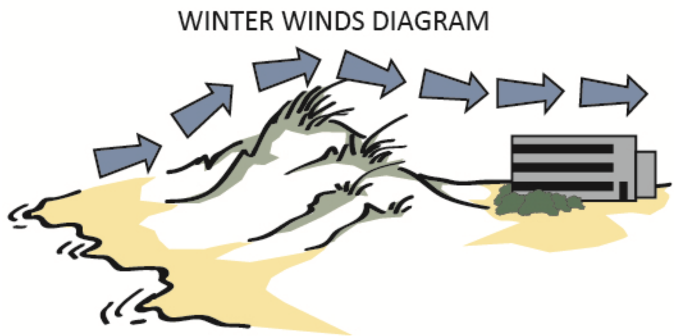


Figure 32 29-6

Figure 32 29-7 Earth berms, shown in this photo, provide thermal mass that helps regulate temperatures inside the building. Collected rainwater is used for irrigation.

CONSIDERATIONS FOR HISTORIC WINDWARD BERMS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses.
  - The energy conservation effectiveness of a windward berm depends on the height of the berm and distance from the structure.
  - "Research conducted on the Great Plains has shown that up to 25 percent energy savings for heating is possible from windbreaks." Berms are even more effective than tree wind breaks because they are solid. (USDA National Agroforestry Center, "Agroforestry: Working Trees for Agriculture," 2012).
  - The effective distance from the structure depends on the berm height. The optimum distance for reducing wind velocity is about one to three times the berm height.
  - A windward berm can reduce heating costs by reducing the wind chill factor. For example, if the outside temperature is 10 degrees F and the wind speed is 20 miles per hour, the wind chill factor is -24 degrees F. When the wind is slowed by the wind break, the wind chill factor is not as severe, thereby reducing the heating load on the building. (Energy.gov, "Landscape Windbreaks and Efficiency," 2012).

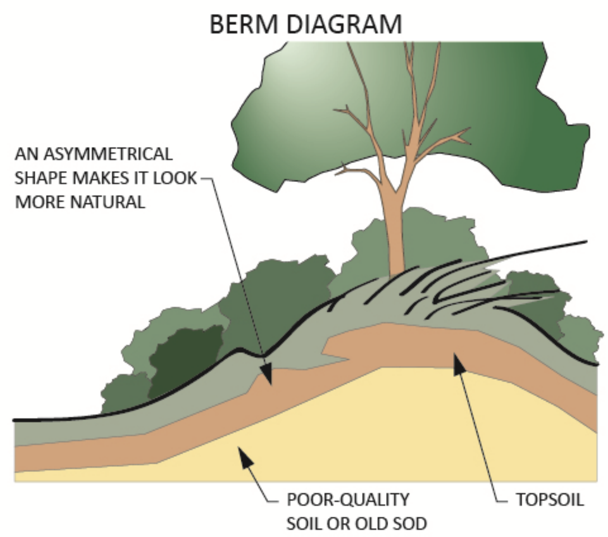


Figure 32 29-8

Figure 32 29-9 Earth berm at the Becton Dickinson Campus Center, Franklin Lakes, NJ.

CONSIDERATIONS FOR HISTORIC WINDWARD BERMS continued:

- **Cost Considerations:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses.
    - As Energy Savings Potential is not knowable in a quantitative sense because of the variables of sites, neither are the Cost Considerations resulting by maintaining a windward berm. The purpose of this Guideline is to make the reader aware that these features are an important part of the historic fabric of a site and also serve as useful energy savers.
    - Potential savings can be developed using infiltration data. These are savings already in place if the berm is existing. Removal of the berm will increase energy costs. The quantity of increase is difficult to predict because it depends on the specific circumstances. The Energy Savings Potential section above can suggest saving predictions.

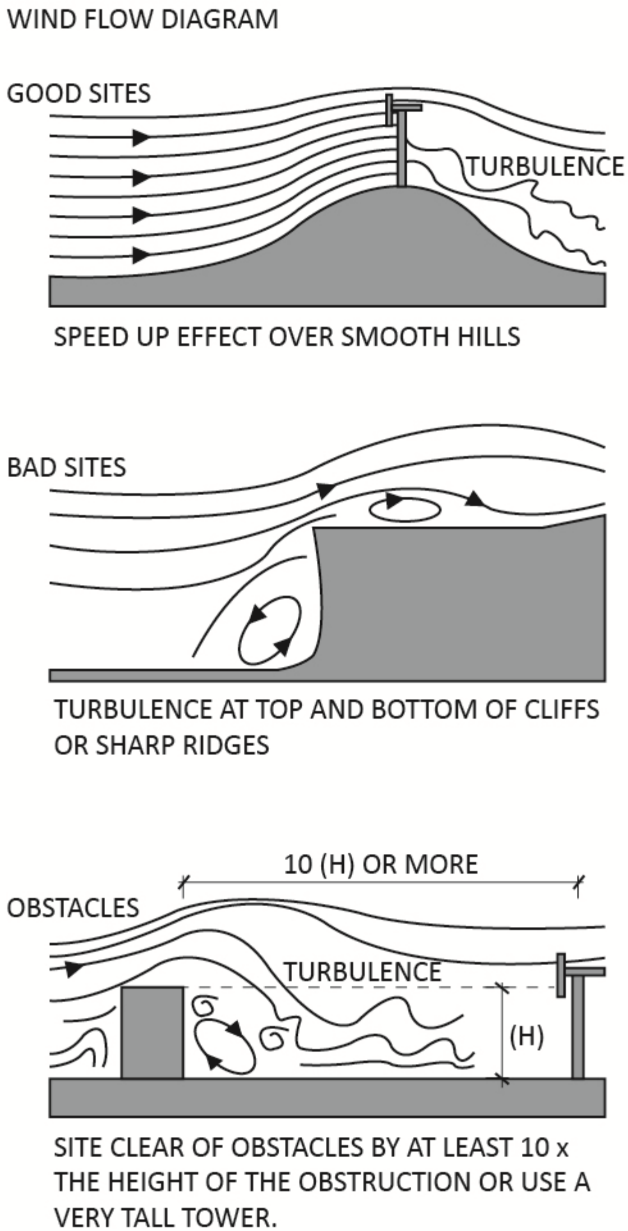


Figure 32 29- 10

CONSIDERATIONS FOR USING HISTORIC TREES FOR SHADING AND SOLAR ACCESS:

- **Approach:**
  - For the purposes of this Guideline, historic trees used for shading are those that are at least 1.5 times as tall as the building they are shading.
  - Because shading is desired in late spring, summer, and early fall, shade trees are most effective on the north and west sides of the structure being shaded. In the Northern Hemisphere, the sun comes up and sets north of east and west, and is in the northern sky much of the day.
  - Shading on the east side is not as necessary since mornings are cooler than midday and afternoon.
  - In cool climates, deciduous trees are preferred for shading because they lose their leaves in winter when direct solar access is desirable.
  - Shading refrigerated air conditioner condensing units reduces the load on these units during the summer.
  - Evaporative air conditioners are more efficient if not shaded, because the water can evaporate more readily in the direct sun. These units also use more water in sunny conditions.

- **Applicable Secretary of the Interior Standards:**
  - 3: Avoid False Historic Changes
  - 5: Distinctive Qualities Preservation
  - 7: Gentle Treatment of Historic Materials

- **Historic Preservation Effects:**
  - Historic, specimen trees are elements in a Cultural Landscape. They may be considered as character defining features of the landscape, as well as shading features.
  - Since trees are living organisms, their health is part of their preservation. Agronomists or urban foresters may need to be consulted on the health and preservation of historic specimen trees.

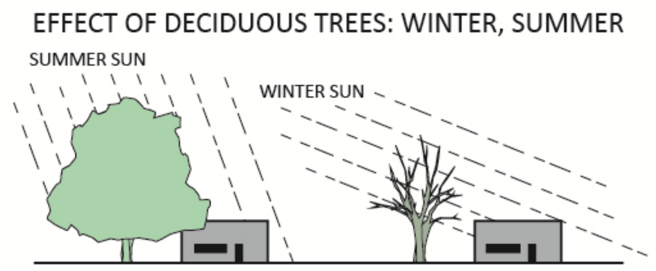


Figure 32 29-11

Figure 32 29-12
Building being shaded by large shade trees, Fort McPherson, GA.

CONSIDERATIONS FOR USING HISTORIC TREES FOR SHADING AND SOLAR ACCESS continued:

- **Energy Savings Potential:** Review Part I, Introduction, Item 3, The Realities of Cost/Benefit Analyses. Because the siting, height, and density of historic shade trees vary so greatly, their energy savings potential cannot be quantified in this Guideline.
  - o The energy conservation effectiveness of a shade tree depends on the height and width of the tree, the density of its foliage, and the amount of the building that it shades.
  - o Trees that shade windows are especially effective because they reduce the "Greenhouse Effect" of direct sun penetrating into a room.
  - o Surfaces in direct sunlight absorb infrared radiation which is "heat" radiation." That effect is what makes one feel warmer in the sun than in the shade. In the shade, a surface absorbs heat until the surface is the same temperature as the air, always cooler than an adjacent surface in direct sun.
  - o Wind can have a cooling effect on surfaces in direct sun or shade.
  - o Adjacent materials that reflect sunlight onto a shaded surface can increase the temperature of the surface.
  - o A multi-month study measured maximum surface temperature reduction due to shade trees ranging from 20 to 45 degrees F for walls and roofs at two buildings (See Sources for Shading on page P2-140: Akbari et al., "Peak Power and Cooling," 1997).
  - o While growing ivy on walls of historic buildings is not recommended because of potential damage to the wall by ivy roots, a study examined the effects of vines on wall temperatures and found reductions of up to 36 degrees F (See Sources for Shading on page P2-140: Sandifer and Givoni, "Thermal Effects of Vines on Wall Temperatures," 2002).

- **Cost Considerations:** Review Part I, Introduction, Item 3**.**
  - o As Energy Savings Potential is not knowable in a quantitative sense because of the variables of sites, density of foliage within the tree, and density of trees, neither are the Cost Considerations resulting by maintaining shade trees knowable in a quantitative way. The purpose of this Guideline is to make the reader aware that these features are an important part of the historic fabric of a site and also serve as useful energy savers.

Sources:
http://www.newton.dep.anl.gov/askasci/wea00/wea00136.htm

http://physics.ucsd.edu/do-the-math/2012/01/basking-in-the-sun/
One square meter can catch about 1000 W, which is comparable to the output of a portable space heater. A dark surface can capture the energy at nearly 100% efficiency, beating (heating?) the pants off of solar photovoltaic (PV) capture efficiency, for instance.

http://www.unce.unr.edu/publications/files/ho/2001/sp0113.pdf

Colorado State University Extension Program:
http://www.ext.colostate.edu/pubs/garden/07225.html,
"Landscaping for Energy Conservation"

CONSIDERATIONS FOR USING HISTORIC TREES FOR SHADING AND SOLAR ACCESS continued:

- **Cost Considerations continued:**
  - Potential cost savings estimates can be developed based upon some of the data provided in Energy Savings Potential. These are savings that are already in place due to the shade tree(s). Removal of the tree(s) will increase energy costs. The quantity of increase is difficult to predict because it depends on the specific circumstances.

Sources for Shading:

Hashem Akbari et al., **"Peak Power and Cooling Energy Savings of Shade Trees,"** *Energy and Buildings* 25, no. 2 (1997): 139-148.

Steven Sandifer and Baruch Givoni, **"Thermal Effects of Vines on Wall Temperatures – Comparing Laboratory and Field collected Data"** (University of California at Los Angeles, 2002); SOLAR 2002, Proceedings of the Annual Conference of the American Solar Energy Society. Reno. NV.

Historically, buildings were designed to conserve energy because energy was scarce and expensive. The goal of using these Guidelines is to help preserve our history, to make historic buildings useful, and to conserve energy once again. The 40 separate Guidelines presented in this report aim to facilitate the planning of rehabilitation projects that will result in improved energy efficiency in historic buildings operated by the Department of Defense (DoD) Legacy Resource Management Program. The legal drivers for this project include Federal Executive Order (EO) 13514. All DoD construction projects, regardless of scope and size, must also meet the Unified Facilities Criteria (UFC). These Guidelines are meant to be used in conjunction with the UFC and provide potential options for meeting the established Criteria. One purpose of the Guidelines is to assist DoD staff who manage historic buildings in meeting the legal obligations that all federal agencies have in the preservation of our national heritage, as detailed in the National Historic Preservation Act of 1966. Perhaps in the future, as the Guidelines have been in the field for a while, there can be feedback on their usefulness and even additional Guidelines prepared as technologies change and improve.

APPENDICES

ACHP. "Advisory Council on Historic Preservation." *www.achp.gov*, August 22, 2006. www.achp.gov.

———. *Sustainability and Historic Federal Buildings*. Washington, D.C: Advisory Council on Historic Preservation, 2011. http://www.achp.gov/docs/SustainabilityAndHP.pdf.

Akbari, Hashem, Dan M. Kurn, Sarah E. Bretz, and James W. Hanford. "Peak Power and Cooling Energy Savings of Shade Trees." *Energy and Buildings* 25, no. 2 (1997): 139–48. doi:10.1016/S0378-7788(96)01003-1.

Alderson, Caroline. *Upgrading Historic Building Lighting*. Technical Preservation Guidelines. Center for Historic Buildings, Office of the Chief Architect, Public Buildings Service, U.S. General Services Administration, April 2009. http://www.gsa.gov/graphics/pbs/TechnicalGuideLightingFINAL2.pdf.

Arsenault, Peter J. "Continuous Insulation Systems for Exterior Walls." *Architectural Record On-Line, Architectural Record Continuing Education Center*, June 2013. http://continuingeducation.construction.com/article.php?L=353&C=1103&P=6.

ASHRAE. *62.1-2013: Ventilation for Acceptable Indoor Air Quality*. ASHRAE Standards. Atlanta: ASHRAE, 2013. https://ashrae.iwrapper.com/ViewOnline/Standard_62.1-2013.

———. *90.1-2004: Energy Standard for Buildings Except Low-Rise Residential Buildings*. ASHRAE Standards. Atlanta: ASHRAE, 2004.

ASHRAE, and Stephanie, Manager of Standards Reiniche. *55-2012: Thermal Environmental Conditions for Human Occupancy*. ANSI/ASHRAE Standards. Atlanta: ASHRAE, 2010.

Autodesk Education Community. "Trombe Wall and Attached Sunspace." *Autodesk Sustainability Workshop*, 2011. http://sustainabilityworkshop.autodesk.com/buildings/trombe-wall-and-attached-sunspace.

Barbose, Galen, Naïm Darghouth, Ryan Wiser, and Joachim Seel. "Tracking the Sun IV: An Historical Summary of the Installed Cost of Photovoltaics in the United States from 1998 to 2010." Lawrence Berkeley National Laboratory, September 2011. http://emp.lbl.gov/sites/all/files/lbnl-5047e.pdf.

Bernstein, Harvey M., Michele A. Russo, Enver Fitch, and Donna Laquidara-Carr, eds. "Smart Market Report: Business Case for Energy Efficient Building Retrofit and Renovation." U.S. Department of Energy, n.d. http://energy.gov/sites/prod/files/2013/12/f5/business_case_for_energy_efficiency_retrofit_renovation_smr_2011.pdf.

BizEE Software Limited. "Heating & Cooling Degree Days - Free Worldwide Data Calculation," 2014. http://www.degreedays.net/.

Breuning, Jörg, and Green Roof Service LLC. “Extensive Green Roofs.” *Green Roof Technology*, 2014. http://www.greenrooftechnology.com/extensive-green-roof.

———. “History.” *Green Roof Technology*, 2014. http://www.greenrooftechnology.com/history-of-green-roofs.

———. “Intensive Green Roofs.” *Green Roof Technology*, 2014. http://www.greenrooftechnology.com/intensive-green-roof.

———. “Semi Intensive Green Roofs.” *Green Roof Technology*, 2014. http://www.greenrooftechnology.com/semi-intensive-green-roof.

Cellulose Insulation Manufacturers Association (CIMA). “CIMA - The Source for Cellulose Insulation Facts and Information,” 2014 2013. http://www.cellulose.org/.

Coleman, Chris. *Voices of the Armory: A Chronicle of the Transformation of a 19th Century Icon into a 21st Century Theater*. Portland: Friends of the Armory and Portland Family of Funds Holdings, Inc., 2006.

ColoradoENERGY.org. “R-Value Table: Insulation Values for Selected Materials.” *Coloradoenergy.org*, August 8, 2014. http://coloradoenergy.org/procorner/stuff/r-values.htm.

Conserve Energy Future. “Cost of Wind Energy,” 2014. http://www.conserve-energy-future.com/WindEnergyCost.php.

Consumers Power Inc. “Line Estimator.” *Consumerspower.org*, (NLA). http://www.consumerspower.org/lines/estimate.php.

CostHelper.com. “CostHelper.com,” 2014. http://www.costhelper.com/.

DAP Products Inc. “The Spec Line,” 2014. http://www.dapspecline.com/products.

Design Recycle Inc. “Design Recycle Inc. Home,” September 2, 2010. http://www.designrecycleinc.com/.

Dictionary.com. “Heat Sink.” *Dictionary.com Unabridged*. Random House, Inc., n.d. http://dictionary.reference.com/browse/heat sink.

———. “Trombe Wall.” *Dictionary.com Unabridged*. Random House, Inc. Accessed October 20, 2014. http://dictionary.reference.com/browse/trombe wall.

Eco-Rate, LLC. “Insulation.” *Www.ecorate.com*, 2014. http://www.ecorate.com/content/products.aspx?cid=28.

Edison Tech Center. “Edison Tech Center Home.” Accessed November 25, 2014. http://www.edisontechcenter.org/.

Energy.gov. “Department of Energy.” Accessed November 21, 2014. http://energy.gov/.

———. “Energy-Efficient Window Treatments,” September 25, 2012. http://energy.gov/energysaver/articles/energy-efficient-window-treatments.

———. “Energy Saver | Department of Energy.” Accessed November 25, 2014. http://energy.gov/energysaver/energy-saver.

———. “Landscape Windbreaks and Efficiency | Department of Energy,” April 13, 2012. http://energy.gov/energysaver/articles/landscape-windbreaks-and-efficiency.

———. “Next-Generation Wind Technology,” n.d. http://energy.gov/eere/next-generation-wind-technology.

———. “Small Solar Electric Systems,” July 15, 2012. http://energy.gov/energysaver/articles/small-solar-electric-systems.

———. “Small Wind Electric Systems,” July 15, 2012. http://energy.gov/energysaver/articles/small-wind-electric-systems.

Energy Informative. “Solar Panels and Home Energy Efficiency - Energy Informative,” 2014. http://energyinformative.org/.

Energy-Models, and EIA.gov. “Average Electric and Gas Cost by State,” March 24, 2014. http://energy-models.com/tools/average-electric-and-gas-cost-state.

EnergyStar.gov. *Federal Leadership in High Performance and Sustainable Buildings*. Memorandum of Understanding, n.d. http://www.energystar.gov/ia/business/Guiding_Principles.pdf.

Fell, David. “Wood and Human Health.” FPInnovations, October 2011. https://fpinnovations.ca/Extranet/Assets/ResearchReportsWP/2862.pdf?tk=-2126464409.

Fisher III, Charles E., ed. *Window Handbook: Successful Strategies for Rehabilitating Windows in Historic Buildings*. [S.l.]: U.S. Department of theInterior National Park Service Preservation Assistance Division and Georgia Institute of Technology, 1986.

Garden, G.K. *Rain Penetration and Its Control*. 40. Canadian Building Digest, 1963.

Gonçalves, Mario D. *Minimizing Moisture Issues: Insulating Solid Masonry Walls*, n.d.

GreenBuildingAdvisor.com. “GreenBuildingAdvisor.com | Designing, Building and Remodeling Green Homes,” 2013. http://www.greenbuildingadvisor.com/.

Grimmer, Anne E., Jo Ellen Hensley, Liz Petrella, and Audrey T. Tepper. *The Secretary of the Interior’s Standards for Rehabilitation & Illustrated Guidelines on Sustainability for Rehabilitation of Historic Buildings*. Washington, D.C: U.S. Department of the Interior, National Park Service, Technical Preservation Services, 2011.

Grimmer, Anne E., Kay D. Weeks, U.S. Department of the Interior, National Park Service., and Technical Preservation Services Division. *New Exterior Additions to Historic Buildings: Preservation Concerns*. Preservation Briefs 14, 2010.

HeatTechProducts.com. “HeatTech Electric Radiant Floor Heating Systems for Tile, Stone and Wood Floors,” 2013. http://www.heattechproducts.com/.

Hensley, Jo Ellen. *Improving Energy Efficiency in Historic Buildings*. Preservation Briefs 3. Washington, DC: National Park Service, U.S. Department of the Interior, Technical Preservation Services, 2011.

Historic Preservation Office. *Insulation*. Trenton: New Jersey Department of Environmental Protection, 2007.

Illuminating Engineering Society. “Footcandle Recommendatios.” Accessed November 25, 2014. http://www.bristolite.com/interfaces/media/Footcandle%20Recommendations%20by%20IES.pdf.

———. *Illuminating Engineering Society of North America (IES) Standards*. Illuminating Engineering Society, n.d.

International Code Council. *International Energy Conservation Code*. [Washington, D.C.]: International Code Council, 2011. https://law.resource.org/pub/us/code/ibr/icc.iecc.2012.pdf.

Kandt, A., E. Hotchkiss, A. Walker, J. Buddenborg, and J. Lindberg. “Implementing Solar PV Projects on Historic Buildings and in Historic Districts.” National Renewable Energy Laboratory, September 2011. http://www.nrel.gov/docs/fy11osti/51297.pdf.

Lighthouse Sustainable Building Centre. *Wood Specification: Acoustics*. Green Building Rating System Guides. naturallywood.com, 2011. http://www.naturallywood.com/sites/default/files/Acoustics.pdf.

Lough, Michael J., and David Altenhofen. “The Rain Screen Principle.” AIA, n.d. http://www.aia.org/aiaucmp/groups/ek_members/documents/pdf/aiab098384.pdf.

Lstiburek, Joseph. *Air Barriers*. Research Report. Building Science Press, 2006. http://www.buildingscience.com/documents/reports/rr-0403-air-barriers.

———. “Understanding Air Barriers.” *Building Science Digest* 104 (October 24, 2006). file:///C:/Users/Rebekah/Downloads/BSD-104_Understanding%20Air%20Barriers.pdf.

Lugano, Fred. “Fixing a Cold, Drafty House.” *Fine Homebuilding*, no. October/November (1996): 92–97.

McDermott, John D., Allen Booz, and Hamilton, Inc. *Assessing the Energy Conservation Benefits of Historic Preservation: Methods and Examples*. Advisory Council on Historic Preservation, 1979.

McDonald, Heather, and Michelle Michael. "Design Guidelines for Department of Defense Historic Buildings and Districts." U.S. Department of Defense, August 2008. http://denix.osd.mil/cr/upload/07-382_FINAL.pdf.

McGuinness, William J., Benjamin Stein, and John Reynolds. *Mechanical and Electrical Equipment for Buildings*. 6th ed. New York: John Wiley & Sons, 1980.

Meadowlark Builders. "Passive Energy Strategies." *Meadowlarkbuilders.com*, 2014. http://meadowlarkbuilders.com/green-building/reference-library/passive-energy-strategies/.

Miller, Charlie. "Extensive Vegetative Roofs." *Whole Building Design Guide*, October 27, 2014. http://www.wbdg.org/resources/greenroofs.php.

Murphy, Tom. "Basking in the Sun." *Do the Math*, January 17, 2012. http://physics.ucsd.edu/do-the-math/2012/01/basking-in-the-sun/.

Myers, John H. *The Repair of Historic Wooden Windows*. Preservation Briefs 9. Washington, DC: U.S. Department of the Interior, National Park Service, Cultural Resources, Heritage Preservation Servicesces, 1981.

NASA, and GISS. "Atmosphere-Ocean Model: Isolation at Specified Location," (NLA). http://aom.giss.nasa.gov/srlocat.html.

National Fire Protection Association. *National Electrical Code.* Quincy, Mass.: National Fire Protection Association, 2010.

National Park Service. "Zion Canyon Visitor Center," October 20, 2014. http://www.nps.gov/zion/naturescience/zion-canyon-visitor-center.htm.

National Park Service, and U.S. Department of the Interior. "Historic Preservation Links -- National Register of Historic Places Official Website--Part of the National Park Service." Accessed November 24, 2014. http://www.nps.gov/nr/preservation_links.htm.

———. "List of SHPO Websites National Register of Historic Places Official Website--Part of the National Park Service." Accessed November 24, 2014. http://www.nps.gov/nr/shpolist.htm.

———. "List of State Historic Preservation Offices' with Digitized Content." Accessed November 24, 2014. http://www.nps.gov/nr/shpoinventories.htm.

National Park Service, U.S. Department of the Interior, and Technical Preservation Services. "Secretary's Standards for Rehabilitation." *Nps.gov*, n.d. www.nps.gov/tps/standards/rehabilitation.htm.

National Renewable Energy Laboratory, E Source, Rocky Mountain Institute, National Association of Energy Service Companies, The Abo Group, Big Ladder Software, The RMH Group, and Cumming. "Advanced Energy Retrofit Guide for Grocery Stores: Practical Ways to Improve Energy Performance." U.S. Department of Energy, July 2013. http://www.nrel.gov/docs/fy13osti/54243.pdf.

National Trust for Historic Preservation. "PreservationNation." *Preservation Nation.org*, 2014. http://www.preservationnation.org/.

———. "Reusing America's Historic National Guard Armories." National Guard Bureau, 2000. http://denix.osd.mil/cr/upload/LRMP_93-0483_Reusing_Historic_National_Guard_Armories_2000.pdf.

National Trust for Historic Preservation, Preservation Green Lab, and New Buildings Institute. "Realizing the Energy Efficiency Potential of Small Buildings." National Trust for Historic Preservation, June 2013. http://www.preservationnation.org/information-center/sustainable-communities/green-lab/small-buildings/130604_NTHP_report_sm.pdf.

NeaCera Terra-cotta Solutions, and Avenere Cladding LLC. "Rainscreen Principles," 2014 2007. http://www.averecladding.com/why-neacera/rainscreen/rainscreen-principles/.

Newton, and Argonne National Laboratory's Educational Programs. "Temperature Measure," June 2012. http://www.newton.dep.anl.gov/askasci/wea00/wea00136.htm.

Old House Web. "Home Remodeling, Repair and Improvement - Products, Ideas and How-To Tips | Old House Web." Accessed November 21, 2014. http://www.oldhouseweb.com/.

Omaha Public Power District (OPPD). "Frequently Asked Questions (FAQ): Commercial-Scale Wind Turbine Generators in the OPPD Service Area," July 14, 2006. http://www.neo.ne.gov/renew/FAQs.pdf.

Oregon.gov. "Biomass Energy: Cost of Production," n.d. http://www.oregon.gov/energy/renew/biomass/Pages/cost.aspx.

Osram Sylvania. "OSRAM SYLVANIA Homepage," 2013. http://www.sylvania.com/en-us/Pages/default.aspx.

Pacific Northwest National Laboratory, PECI, and U.S. Department of Energy. "Advanced Energy Retrofit Guide for Office Buildings: Practical Ways to Improve Energy Performance." U.S. Department of Energy, September 2011. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20761.pdf.

Pacific Power. "Commercial Price Comparison," 2014. https://www.pacificpower.net/about/rr/cpc.html.

Peck, Steven, and Monica Kuhn. "Design Guidelines for Green Roofs." Canada Mortgage and Housing Corporation and the Ontario Association of Architects, 2003. http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/upload/Design-Guidelines-for-Green-Roofs.pdf.

"Performance Evaluation of Retrofitted Solid Masonry Exterior Walls." Canada Mortgage and Housing Corporation, 2007. http://www.cmhc-schl.gc.ca/odpub/pdf/65033.pdf.

Perry, Pam. "Solar Panel Savings," 2006 2005. http://www.trustyguides.com/solar-panels3.html.

Pickles, David, Ian Brocklebank, and Chris Wood, eds. *Energy Efficiency in Historic Buildings: Draught-Proofing Windows and Doors*. England: English Heritage, 2010.

———. , eds. *Energy Efficiency in Historic Buildings: Early Cavity Walls*. England: English Heritage, 2010.

———. , eds. *Energy Efficiency in Historic Buildings: Insulating Solid Ground Floors*. England: English Heritage, 2010.

———. , eds. *Energy Efficiency in Historic Buildings: Insulating Solid Walls*. England: English Heritage, 2010.

———. , eds. *Energy Efficiency in Historic Buildings: Insulating Timber-Framed Walls*. England: English Heritage, 2010.

———. , eds. *Energy Efficiency in Historic Buildings: Insulation of Suspended Timber Floors*. England: English Heritage, 2010.

Preservapedia. "Preservapedia," September 5, 2013. http://preservapedia.org/.

Preservation Green Lab. "The Greenest Building: Quantifying the Environmental Value of Building Reuse." National Trust for Historic Preservation, 2011. http://www.preservationnation.org/information-center/sustainable-communities/green-lab/lca/The_Greenest_Building_lowres.pdf.

Rice, Jennifer, Robert A. Kozak, Michael J. Meitner, and David H. Cohen. "Appearance Wood Products and Psychological Well-Being." *Wood and Fiber Science* 38, no. 4 (2006): 644–59.

Robinson, M.L., and Carole Eddington. "Shade Factors in Southern Nevada Using Trees and Shrubs for Shading Outdoor Spaces." University of Nevada, Reno. Accessed November 24, 2014. http://www.unce.unr.edu/publications/files/ho/2001/sp0113.pdf.

Saadatian, Omidreza, K. Sopian, C.H. Lim, Nilofar Asim, and M.Y. Sulaiman. "Trombe Walls: A Review of Opportunities and Challenges in Research and Development." *Renewable and Sustainable Energy Reviews*, Amerindian Spaces in American Art, 16 (2012): 6340–51.

Sandifer, Steven, and Baruch Givoni. "Thermal Effects of Vines on Wall Temperatures - Comparing Laboratory and Field Collected Data." University of California at Los Angeles, 2002. http://www.sbse.org/awards/docs/Sandifer.pdf.

Solar Power Authority. "Solar Power Authority: Independent Cleantech Insights." *Solarpowerauthority.com*, 2014. http://solarpowerauthority.com/.

State Energy Conservation Office, and Texas Energy Conservation Office. "Infinite Power of Texas," (NLA). http://www.infinitepower.org/index.htm.

STEP Warmfloor. "Radiant Underfloor Heating, Heated Floors, Electric Floor Heating - STEP Warmfloor," 2012. http://www.warmfloor.com/.

Talbot, F. Brian, Peter Adriaens, and Corrie Clark. "Green Roof Valuation: A Probabilistic Economic Analysis of Environmental Benefits." *Environmental Science & Technology* 42, no. 6 (2008): 2155–61.

The Engineering ToolBox. "Heat Loss through Building Elements due to Transmission." Accessed November 25, 2014. http://www.engineeringtoolbox.com/heat-loss-transmission-d_748.html.

Torcellini, P., and S. Pless. "Trombe Walls in Low-Energy Buildings: Practical Experiences." Denver: National Renewable Energy Laboratory, 2004. http://www.nrel.gov/docs/fy04osti/36277.pdf.

United States Gypsum Company. *Gypsum Construction Handbook*. Chicago: United States Gypsum Company, 1978.

U.S. Congress. *An Act to Ensure Jobs for Our Future with Secure, Affordable, and Reliable Energy*. Act. Washington, D.C: U.S. Congress, 2005.

USDA National Agroforestry Center. "Agroforestry: Working Trees for Agriculture." USDA National Agroforestry Center, U.S. Forest Service, NRCS, 2012. http://nac.unl.edu/documents/workingtrees/brochures/wta.pdf.

———. "Great Plains Windbreak Renovation and Innovation Conference," July 24, 2012. http://nac.unl.edu/multimedia/conferences/Great_Plains/windbreakrenovation20120724.htm.

———. "Windbreaks." Accessed November 24, 2014. http://nac.unl.edu/windbreaks.htm.

U.S. Department of Defense. "DENIX - Cultural Resources, Historic Buildings and Structures, Inventories and Evaluation." Accessed November 21, 2014. http://www.denix.osd.mil/cr/HistoricBuildingsStructures/InventoriesEvaluation.cfm.

———. "Department of Defense Fiscal Year 2007 Energy Management Implementation Plan." U.S. Department of Defense, January 2007. http://www.acq.osd.mil/ie/energy/energymgmt_report/fy06/FY_2007_Implementation_Plan.pdf.

———. *Fiscal Year 2007: Energy Management Implementation Plan*. Plan. U.S. Department of Defense, January 2007. http://www.acq.osd.mil/ie/energy/energymgmt_report/fy06/FY_2007_Implementation_Plan.pdf.

U.S. Department of Defense, U.S. Environmental Protection Agency, and U.S. Department of Energy. "Strategic Environmental Research and Development Program, Environmental Security Technology Certification Program." Accessed December 12, 2014. https://www.serdp-estcp.org/.

U.S. Department of Energy. “Berkeley Lab, Lawrence Berkeley National Laboratory,” 2012. http://newscenter.lbl.gov/news-releases/2011/09/15/tracking-the-sun-iv/.

———. “Building Energy Codes Program,” July 17, 2014. http://www.energycodes.gov/adoption/states.

———. “Buildings Energy Data Book,” March 2012. http://buildingsdatabook.eere.energy.gov/ChapterIntro3.aspx.

———. “Database of State Incentives for Renewables & Efficiency (DSIRE),” 2014 2013. http://dsireusa.org/incentives/index.cfm?EE=0&RE=1&PV=0&ST=0&technology=Biomass&sh=1.

———. “Energy Savers Tips: Windows.” *Energy.gov*, May 15, 2012. http://www.energysavers.gov/tips/windows.cfm.

———. “Guide to Integrating Renewable Energy in Federal Construction,” August 10, 2012. http://www2.eere.energy.gov/femp/reconstructionguide/project_funding.html.

———. “High Performance Federal Buildings.” *Energy Efficiency and Renewable Energy*, November 4, 2004. www.eere.energy.gov/femp/highperformance/index.cfm.

———. “Landscaping for Energy Efficiency.” Energy Efficiency and Renewable Energy Clearinghouse, April 1995. http://www1.eere.energy.gov/library/pdfs/16632.pdf.

———. “Tankless or Demand-Type Water Heaters.” *Energy.gov*, May 2, 2012. http://energy.gov/energysaver/articles/tankless-or-demand-type-water-heaters.

———. “What Is Wind Power?” *WINDExchange*, May 14, 2014. http://apps2.eere.energy.gov/wind/windexchange/what_is_wind.asp.

U.S. Department of Energy, and Federal Energy Management Program (FEMP). “Biomass for Electricity Generation.” *Whole Building Design Guide*, August 4, 2011. http://www.wbdg.org/resources/biomasselectric.php.

U.S. Energy Information Administration. “Biomass Explained,” May 30, 2014. http://www.eia.gov/energyexplained/index.cfm?page=biomass_home.

———. “Eia.gov,” n.d. http://www.eia.gov/.

———. “Electric Power Monthly with Data for July 2014.” U.S. Department of Energy, September 2014. http://www.eia.gov/electricity/monthly/pdf/epm.pdf.

U.S. Environmental Protection Agency. "Energy Star," n.d. http://www.energystar.gov/.

———. "Guiding Principles for Constructed Treatment Wetlands: Providing for Water Quality and Wildlife Habitat." U.S. Environmental Protection Agency, October 2000. http://water.epa.gov/type/wetlands/constructed/upload/guiding-principles.pdf.

———. "Heat Island Effect," July 31, 2014. http://www.epa.gov/heatisland/.

———. "Heat Island Effect: Green Roofs," November 22, 2013. http://www.epa.gov/heatisland/mitigation/greenroofs.htm.

———. "Life Cycle Assessment (LCA)." *Risk Management Sustainable Technology*, August 5, 2014. http://www.epa.gov/nrmrl/std/lca/lca.html#define.

———. "United States Environmental Protection Agency," n.d. http://www.epa.gov/.

U.S. General Services Administration. "Center for Historic Buildings." *Gsa.gov*, July 2, 2013. http://www.gsa.gov/portal/content/104441.

———. "GSA Home." Accessed November 21, 2014. http://www.gsa.gov/portal/category/100000.

Van Citters Preservation, and Cherry/See/Reames Architects. *Building Efficiency Guidance: Sustainability and the Historic Building*. Project Number 09-452. Department of Defense Legacy Program, 2009.

Walker, L., and S. Newman. *Landscaping for Energy Conservation*. Fact Sheet. Gardening Series - Basics. Colorado State University Extension, March 2009. http://www.ext.colostate.edu/pubs/garden/07225.pdf.

WBDG Historic Preservation Subcommittee. "Historic Preservation | Whole Building Design Guide," September 15, 2014. http://www.wbdg.org/design/historic_pres.php.

Weeks, Kay D., Anne Grimmer, and Heritage Preservation Services. "The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring, & Reconstructing Historic Buildings." Guidelines. *Nps.gov*, 2001. http://www.nps.gov/tps/standards/four-treatments/standguide/index.htm.

Weeks, Kay D., and United States. "Building Exterior: Windows." In *The Secretary of the Interior's Standards for the Treatment of Historic Properties: With Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings*, 35–37. Washington, D.C: U.S. Department of the Interior, National Park Service, Cultural Resource Stewardship and Parnterships, Heritage Preservation Services, 1995.

Williams College. "Passive Solar Design." *Sustainability*, 2014. http://sustainability.williams.edu/green-building-basics/passive-solar-design.

Wood, Chris, Bill Bordass, and Paul Baker. *Research into the Thermal Performance of Traditional Windows: Timber Sash Windows*. Research Report. England: English Heritage, October 2009. https://www.english-heritage.org.uk/publications/thermal-performance-traditional-windows/thermal-performance-traditional-windows.pdf.

WoodWORKS!, Canadian Wood Council, US WoodWorks, and Canada Wood. "Wood in Healthcare," September 2012. http://www.naturallywood.com/sites/default/files/Wood-in-Healthcare.pdf.

Wright, Chuck. "Insulation Investment Calculator," n.d. http://chuck-wright.com/calculators/insulpb.html.

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Part II:

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Chart 00 01-1 **Gas Usage Over 1 Year in Therms**. Example chart that can be found in a utility bill. Graphic by Cherry/See/Reames Architects, 2012.

Guideline 01 01:

Chart 01 01-1 **Expected Operating Cost Decreases from Energy Efficiency Retrofit/Renovation Activities.** Chart by Stephen Mora for Cherry/See/Reames Architects, 2014. Chart based on information from "Smart Market Report: Business Case for Energy Efficient Building Retrofit and Renovation," http://energy.gov/sites/prod/files/2013/12/f5/business_case_for_energy_efficiency_retrofit_renovation_smr_2011.pdf, 17.

Chart 01 01-2 **General Wind Turbine Sizes.** Chart based on information from "Wind Electricity Generation," http://practicalaction.org/docs/technical_information_service/wind_electricity_generation.pdfl.

Chart 01 01-3 **Waste to Energy Chart.** Chart by Stephen Mora for Cherry/See/Reames Architects, 2014. Based on diagrams by the U.S. EPA, *Municipal Solid Waste in the United States: 2011 Facts and Figures*, from http://www.eia.gov/energyexplained/index.cfm?page=biomass_waste_to_energy, 2013.

Chart 01 01-4 **Cost of Biomass Energy Processes in Oregon Chart.** Chart made by Rebekah Bellum for Cherry/See/Reames Architects, 2014. Based on information from "Biomass Energy: Cost of Production," http://www.oregon.gov/energy/renew/biomass/Pages/cost.aspx.

Guideline 01 02:

Chart 01 02-1 **Residential Site Energy Consumption by End Use Chart.** Chart by Stephen Mora for Cherry/See/Reames Architects, 2014. Based on chart from U.S. Department of Energy, *Buildings Energy Data Book*, "Chapter 2: Residential Sector," http://buildingsdatabook.eere.energy.gov/ChapterIntro2.aspx.

Chart 01 02-2 **2003 Commercial Building Energy Intensity by Building Activity Graph.** Graph by Stephen Mora for Cherry/See/Reames Architects, 2014. Based on chart from http://buildingsdatabook.eere.energy.gov/docs/DataBooks/2011_BEDB.pdf, 114, 2011. Chart compilation from National Trust for Historic Preservation, Preservation Green Lab in partnership with the New Buildings Institute, Realizing the Energy Efficiency Potential of Small Buildings, June 2013.

Chart 01 02-3 **Percent Energy Use by Building System in Offices Chart.** Chart by Alyson Reece for Cherry/See/Reames Architects, 2014. Chart based on information from Pacific Northwest National Laboratory, PECI, and U.S. Department of Energy, "Advanced Energy Retrofit Guide for Office Buildings: Practical Ways to Improve Energy Performance" (U.S. Department of Energy, September 2011), 20, http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20761.pdf.

Chart 01 02-4 **Electricity Use Chart.** Chart by Alyson Reece for Cherry/See/Reames Architects, 2014. Chart based on information from the U.S. Department of Energy.

Chart 01 02-5 **Gas Use Chart.** Chart by Alyson Reece for Cherry/See/Reames Architects, 2014. Chart based on information from the U.S. Department of Energy.

Guideline 03 31:

Chart 03 31-1 **Commercial Sector Energy Usage.** Chart by U.S. Energy Information Administration, Commercial Sector Energy Consumption Estimates 1949-2012, Released October 19, 2011, Updated August, 2012.

Guideline 05 41:

Chart 05 41-1 **Primary Air Infiltration Locations Chart.** Chart by Alyson Reece for Cherry/See/Reames Architects, 2014. Chart based on information from the U.S. Department of Energy, Energy Savers Data.

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Chart 23 08-1 **ASHRAE Standard 55: Acceptable range of operative temperature and humidity for spaces**. Diagram from ASHRAE Standard 55, ASHRAE; Reiniche, Stephanie, Manager of Standards 2010.

Chart 23 08-2 **HVAC System Options**. Diagram by Edie Cherry for Cherry/See/Reames Architects, 2012.

Guideline 23 21:

Chart 23 21-1 **Typical Geothermal Operating Cost Comparisons Graph.** Graph by Stephen Mora for Cherry/See/Reames Architects, 2014. Based on graph from Martha's Vineyard Geothermal Heating and Cooling Systems, http://mvgeothermal.com/why_geothermal.php, 2014.

Guideline 23 40:

Chart 23 40-1 **Cost Comparison of the Different Types of Systems Chart.** Chart by Rebekah Bellum for Cherry/See/Reames Architects, 2014. Based on information provided by The Response Group.

Chart 23 40-2 **Heating System Comparisons Chart.** Chart by Al Pielhau for Cherry/See/Reames Architects, 2014.

Guideline 26 22:

Chart 26 22-1 **Cost Comparison of the Different Types of Systems Chart.** Chart by Rebekah Bellum for Cherry/See/Reames Architects, 2014. Based on information provided by The Response Group.

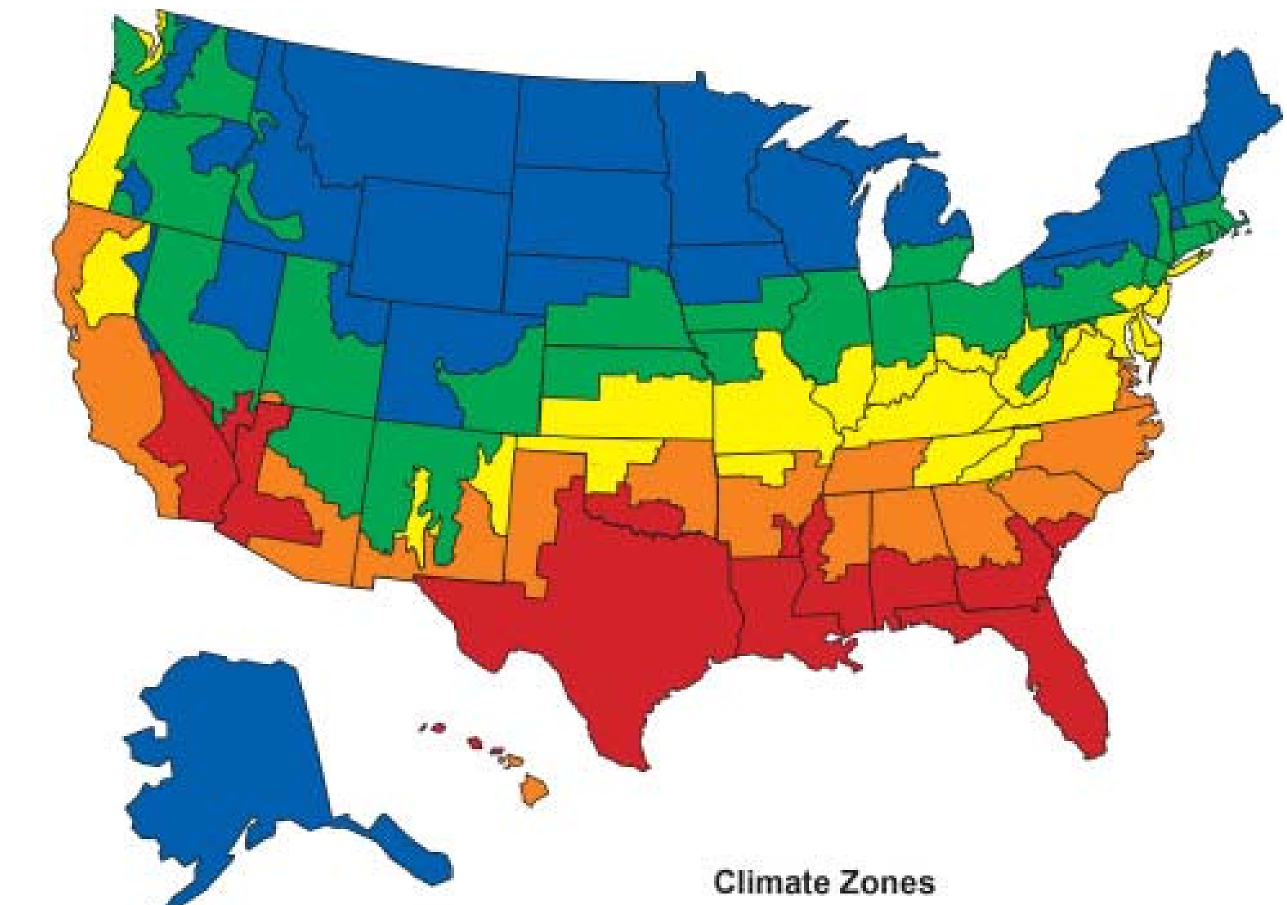
Chart 26 22-2 **Heating System Comparisons Chart.** Chart by Al Pielhau for Cherry/See/Reames Architects, 2014.

Guideline 26 51:

- **Kwh to BTU:**
    - 1 Kwh = 3412.2 BTU
    - 1 BTU = 0.0000293 Kwh
- **Therm to BTU:**
    - 1 Therm = 100,000 BTU
- **Gallons of fuel oil to BTU:** This value changes depending on the type of fuel used, quality of fuel, and in some cases, the pressure (www.generatorjoe.net/html/energy.html).
    - Propane: 1 gallon = 91,500 BTU
    - Gasoline: 1 gallon = 125,000 BTU
    - Kerosene: 1 gallon = 135,000 BTU
    - #2 Oil: 1 gallon = 138,500 BTU
    - Diesel: 1 gallon = 139,200 BTU
    - #6 Oil: 1 gallon = 153,200 BTU

U.S Climate Zones for 2003 CBECS (updated with corrections February 2012)

http://www.eia.gov/emeu/cbecs/climate_zones.html



Zone 1 is less than 2,000 CDD and greater than 7,000 HDD.

Zone 2 is less than 2,000 CDD and 5,000-7,000 HDD.

Zone 3 is less than 2,000 CDD and 4,000-5,499 HDD.

Zone 4 is less than 2,000 CDD and less than 4,000 HDD.

Zone 5 is 2,000 CDD or more and less than 4,000 HDD.

DETAILS of the U.S. Climate Zones Map

The CBECS climate zones are groups of climate divisions, as defined by the National Oceanic and Atmospheric Administration (NOAA), which are regions within a state that are as climatically homogeneous as possible. Each NOAA climate division is placed into one of five CBECS climate zones based on its 30-year average heating degree-days (HDD) and cooling degree-days (CDD) for the period 1971 through 2000.

There are 359 NOAA climate divisions within the 50 U.S. states. Boundaries of these divisions generally coincide with county boundaries, except in the western U.S., where they are based largely on drainage basins. For a map of all the NOAA climate divisions in the U.S., see http://www.esrl.noaa.gov/psd/data/usclimdivs/data/map.html. For individual state maps that show the NOAA climate divisions by county, see http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/CLIM_DIVS/states_counties_climate-divisions.shtml.

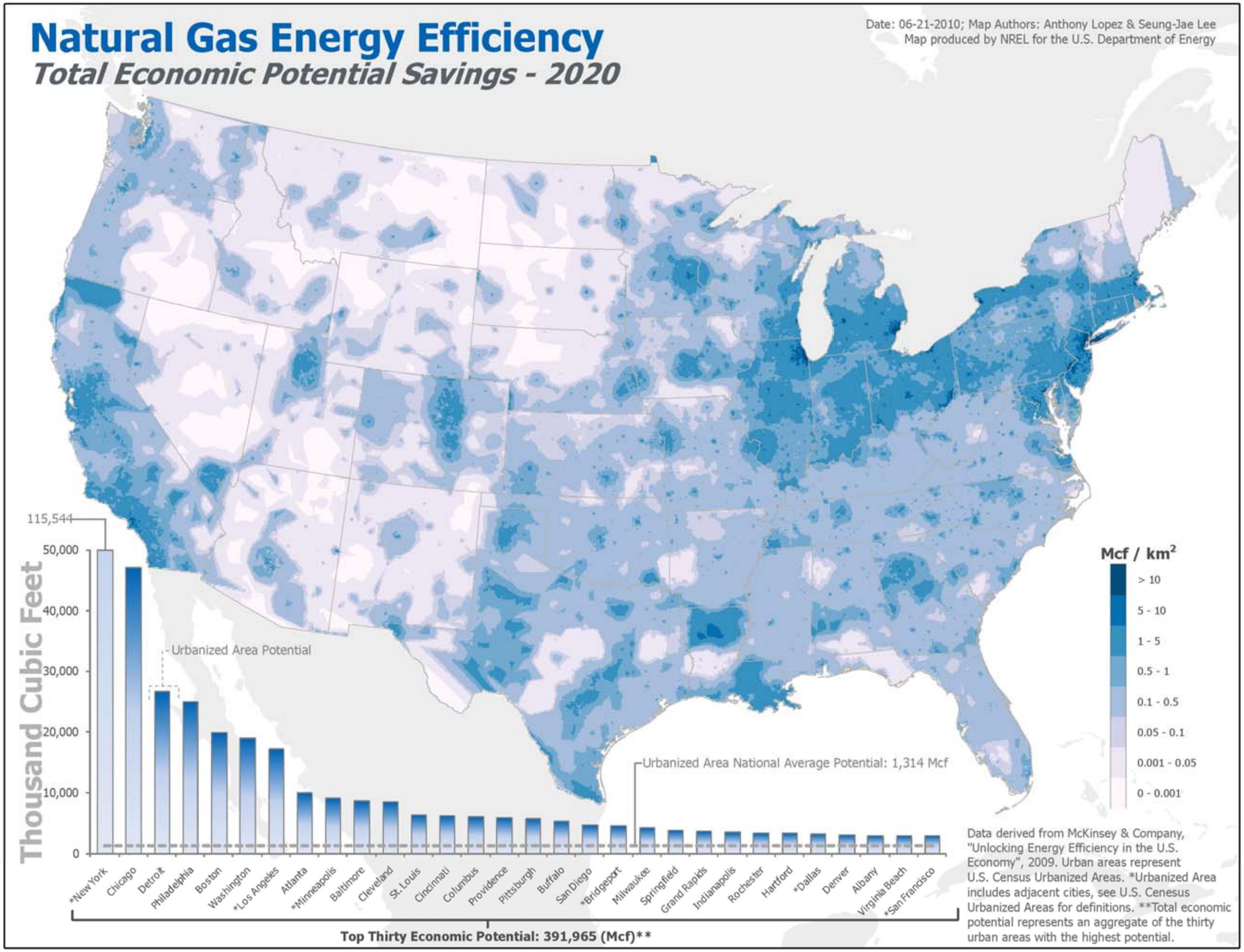
Each building in the CBECS is assigned a CBECS climate zone based on the 30-year average (1971-2000) HDD and CDD (base 65 degrees Fahrenheit) for the NOAA climate division in which the weather station closest to the sampled building is located.

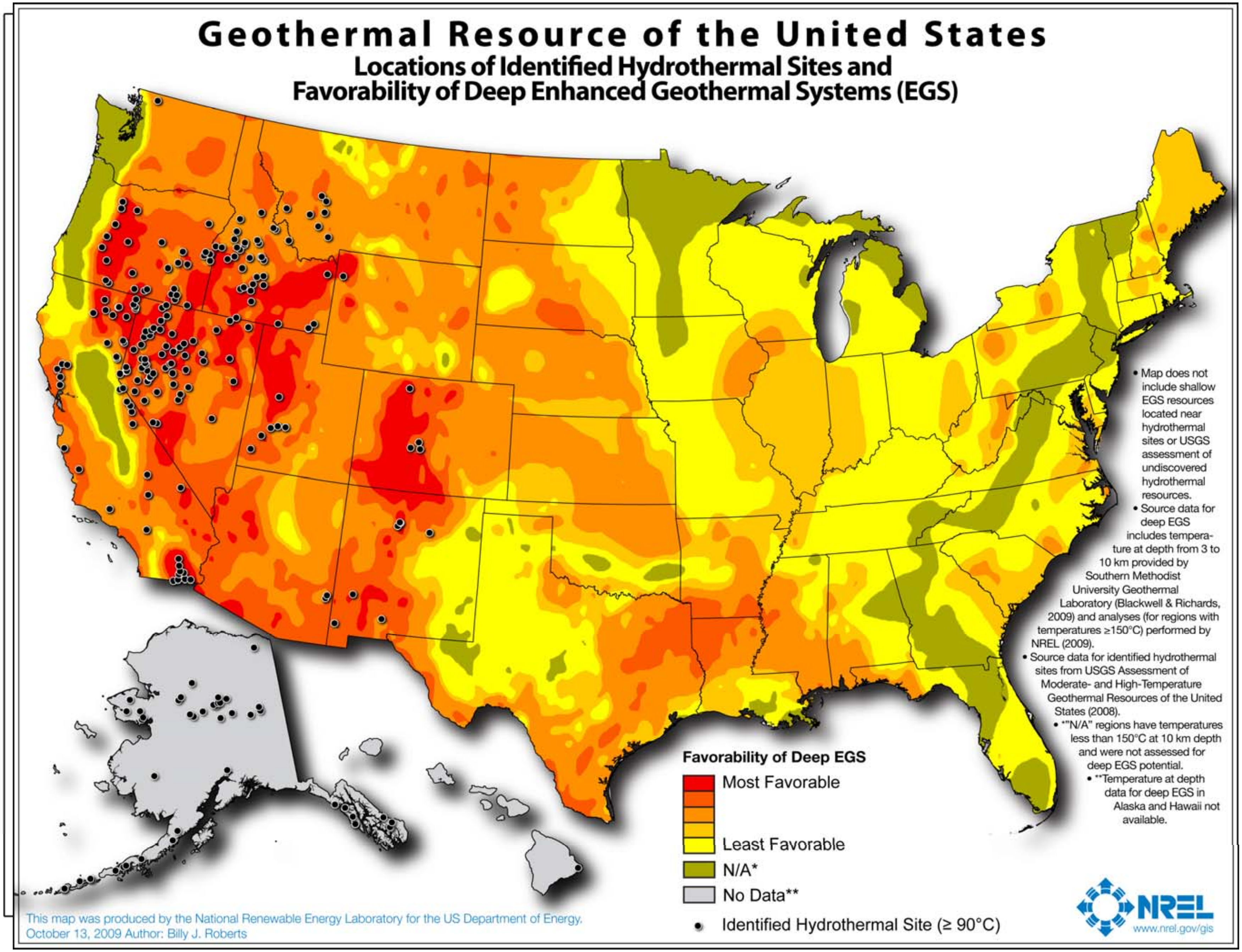
Specific questions on this product may be directed to: Joelle Michaels
joelle.michaels@eia.doe.gov
CBECS Manager

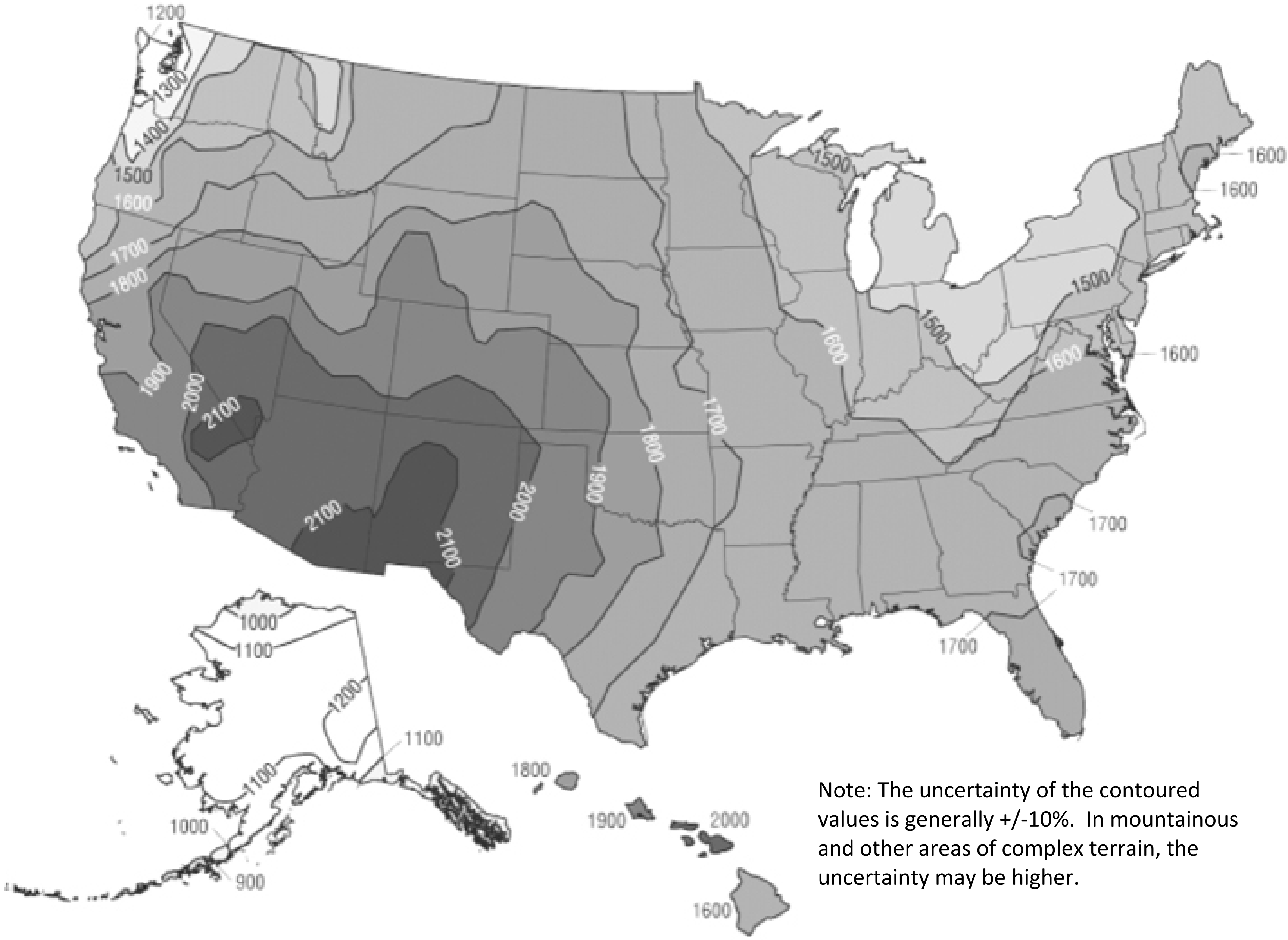
APPENDIX F: EXPANDED RIGID INSULATION TABLE

Expanded Rigid Insulation Table showing how the inputs are derived. This table will also appear in Part 1, Introduction, Item 3 with blank inputs for individual use. Values cannot be factored until the inputs are set. If viewing as a Word document, double click inside the table and add the input values.

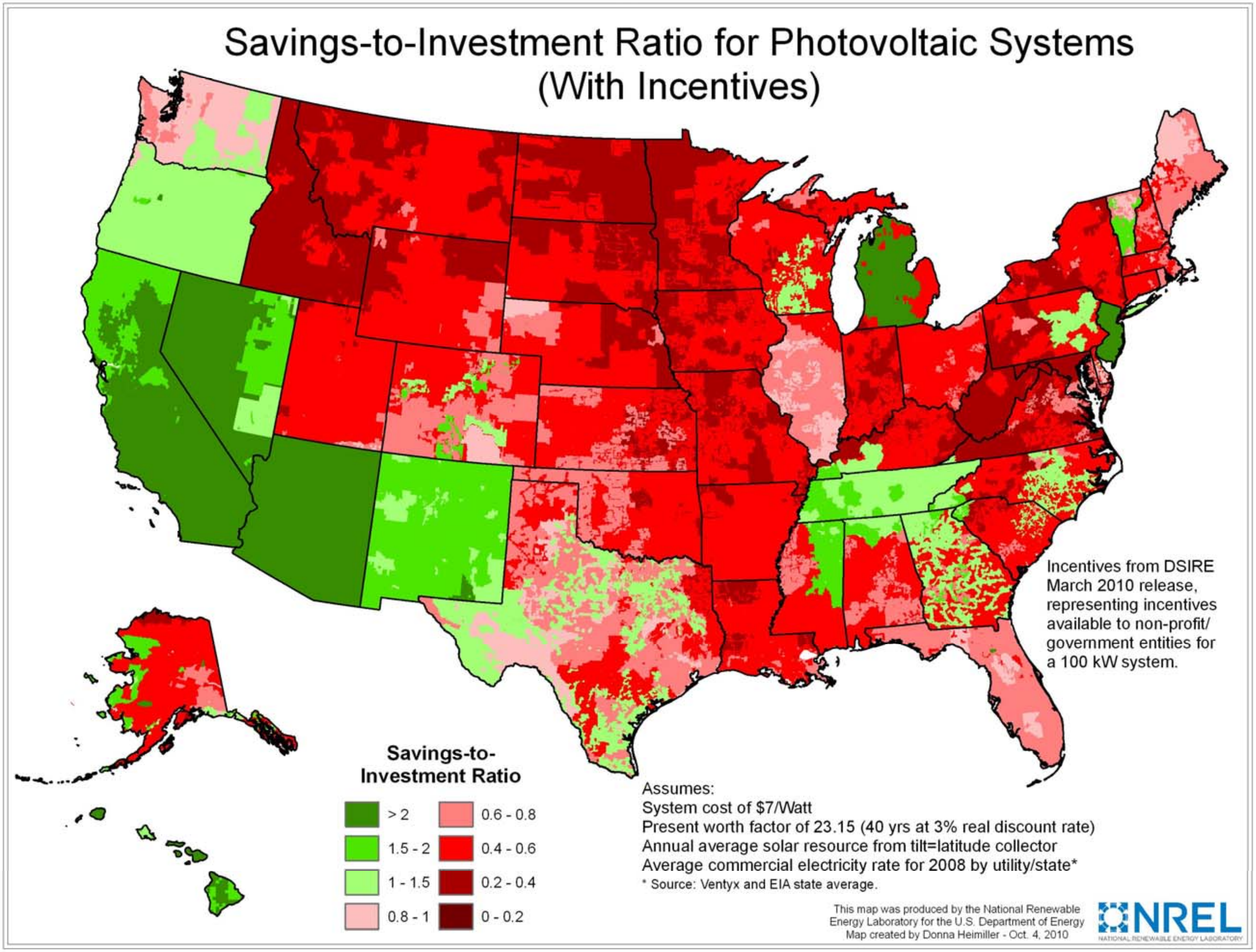
DESCRIPTION	CALCULATION	INPUTS	UNITS
Initial R-value			(hr x sf x degF)/BTU
Final R-value			(hr x sf x degF)/BTU
HDD			days x degF/yr
CDD			days x degF/yr
Heating Efficiency			% gas heating efficiency
Cooling Efficiency			COP
Cost of Gas		$ -	$/therm
Cost of Electricity		$ -	$/kWh
Area of Insulation			sf
Inverse of initial R-value	=1/(Initial R-value)	#DIV/0!	BTU/(hr x sf x degF)
Constant	=hours in a day	24	hours/day
Initial Heating Energy	=1/(Initial R-value) x (hours in a day) x (Area of Insulation) x HDD	#DIV/0!	BTU/yr
Convert to Therms	=(Initial Heating Energy)/(100,000 x Heating Efficiency)	#DIV/0!	therms/yr
Initial Heating Energy Cost	=Therms/yr x $/therm	#DIV/0!	$ heating/year
Initial Cooling Energy	=1/(Initial R-value) x (hours in a day) x (Area of Insulation) x CDD	#DIV/0!	BTU/yr
Convert to kWh	=Initial Cooling Energy / 3,412	#DIV/0!	kWh
Initial Cooling Energy Cost	=kWh/COP x $/kWh	#DIV/0!	$/year
Initial Total Cost Calculation	=Initial Heating Energy Cost + Initial Cooling Energy Cost	#DIV/0!	$/year
Inverse of final R-value	=1/(Final R-value)	#DIV/0!	BTU/(hr x sf x degF)
Final Heating Energy	=1/(Final R-value) x (hours in a day) x (Area of Insulation) x HDD	#DIV/0!	BTU/yr
Convert to Therms	=(Final Heating Energy)/(100,000 x Heating Efficiency)	#DIV/0!	therms/yr
Final Heating Energy Cost	=Therms/yr x $/therm	#DIV/0!	$ heating/year
Final Cooling Energy	=1/(Final R-value) x (hours in a day) x (Area of Insulation) x CDD	#DIV/0!	BTU/yr
Convert to kWh	=Final Cooling Energy / 3,412	#DIV/0!	kWh
Final Cooling Energy Cost	=kWh/COP x $/kWh	#DIV/0!	$/year
Final Total Cost Calculation	=Final Heating Energy Cost + Final Cooling Energy Cost	#DIV/0!	$/year
Total Cost Savings	=Difference of Final Energy Cost and Initial Energy Cost	#DIV/0!	$/year


Natural Gas Energy Efficiency
Total Economic Potential Savings - 2020
Date: 06-21-2010; Map Authors: Anthony Lopez & Seung-Jae Lee
Map produced by NREL for the U.S. Department of Energy
Thousand Cubic Feet
115,544
50,000
40,000
30,000
20,000
10,000
0
Urbanized Area Potential
Urbanized Area National Average Potential: 1,314 Mcf
*New York
Chicago
Detroit
Philadelphia
Boston
Washington
*Los Angeles
Atlanta
*Minneapolis
Baltimore
Cleveland
St. Louis
Cincinnati
Columbus
Providence
Pittsburgh
Buffalo
San Diego
*Bridgeport
Milwaukee
Springfield
Grand Rapids
Indianapolis
Rochester
Hartford
*Dallas
Denver
Albany
Virginia Beach
*San Francisco
Top Thirty Economic Potential: 391,965 (Mcf)**
Mcf / km^2
> 10
5 - 10
1 - 5
0.5 - 1
0.1 - 0.5
0.05 - 0.1
0.001 - 0.05
0 - 0.001
Data derived from McKinsey & Company, "Unlocking Energy Efficiency in the U.S. Economy", 2009. Urban areas represent U.S. Census Urbanized Areas. *Urbanized Area includes adjacent cities, see U.S. Cenesus Urbanized Areas for definitions. **Total economic potential represents an aggregate of the thirty urban areas with the highest potential.


Geothermal Resource of the United States
Locations of Identified Hydrothermal Sites and
Favorability of Deep Enhanced Geothermal Systems (EGS)
• Map does not include shallow EGS resources located near hydrothermal sites or USGS assessment of undiscovered hydrothermal resources.
• Source data for deep EGS includes temperature at depth from 3 to 10 km provided by Southern Methodist University Geothermal Laboratory (Blackwell & Richards, 2009) and analyses (for regions with temperatures ≥150°C) performed by NREL (2009).
• Source data for identified hydrothermal sites from USGS Assessment of Moderate- and High-Temperature Geothermal Resources of the United States (2008).
• *"N/A" regions have temperatures less than 150°C at 10 km depth and were not assessed for deep EGS potential.
• **Temperature at depth data for deep EGS in Alaska and Hawaii not available.
Favorability of Deep EGS
Most Favorable
Least Favorable
N/A*
No Data**
Identified Hydrothermal Site (≥ 90°C)
NREL
www.nrel.gov/gis
This map was produced by the National Renewable Energy Laboratory for the US Department of Energy.
October 13, 2009 Author: Billy J. Roberts



Note: The uncertainty of the contoured values is generally +/-10%. In mountainous and other areas of complex terrain, the uncertainty may be higher.


Savings-to-Investment Ratio for Photovoltaic Systems
(With Incentives)
Incentives from DSIRE March 2010 release, representing incentives available to non-profit/ government entities for a 100 kW system.
Savings-to-Investment Ratio
> 2
1.5 - 2
1 - 1.5
0.8 - 1
0.6 - 0.8
0.4 - 0.6
0.2 - 0.4
0 - 0.2
Assumes:
System cost of $7/Watt
Present worth factor of 23.15 (40 yrs at 3% real discount rate)
Annual average solar resource from tilt=latitude collector
Average commercial electricity rate for 2008 by utility/state*
* Source: Ventyx and EIA state average.
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy
Map created by Donna Heimiller - Oct. 4, 2010
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Source: www.bristolite.com/interfaces/media/Footcandle%20Recommendations%20by%20IES.pdf (Iron and Steel Manufacturing continued on next page.)

IES Footcandle Recommendations

The following selected footcandle ranges represent the Illuminating Engineer Society's (IES) current illuminance recommendations. Indiviudal applications will determing exact foot-candle levels. Please refer to the IES Lighitng Handbook for more detailed evaluation.

Airplane Manufacturing
- Drilling, riveting, screw fastening.....75
- Final assemble, hangar.....100
- Inspection.....50-200
- Welding.....50

Assembly
- Rough easy seeing.....20-50
- Rough difficult seeing.....50-100
- Medium.....100-200
- Fine.....200-500(a)
- Extra fine.....500-1000(a)

Auditoriums
- Social activities.....5-10
- Assembly only.....10-20
- Exhibitions.....10-20

Automobile Manufacturing
- Final assembly, finishing, inspecting.....200
- Body & chassis assembly.....100
- Body parts manufacturing.....100
- Frame assembly.....50

Banks
- Lobby general.....10-50
- Writing areas.....20-70
- Teller stations, posting & keypunch.....50-150

Garages-Motor Vehicles
- Storage.....5
- Traffic Lanes
  - Parking garage.....10
  - Service garage.....10-20
  - Entrances.....50
  - Repair area.....50-100

Gymnasiums
- Assemblies.....10
- General exercise & recreation.....30
- Exhibitions, matches.....50

Hospitals
- Rooms.....10-30
- Corridors.....5-30
- Emergency rooms.....50-100
- Operating rooms.....100-200

Hotels
- Bathrooms.....20-50
- Bedrooms for reading.....20-50
- Corridors, elevators and stairs.....10-20
- Front desk.....50-100
- Linen room
  - Sewing.....100-200
  - General.....10-20
- Lobby
  - General lighting.....10-20
  - Reading and working areas.....20-50

Iron & Steel Manufacturing
- Stock, hot top, checker cellar, calcining.....10-30
- Building, slag pits, stripping yard.....20

- Mail sorting.....50-100
- Off-set printing and duplicating area.....20-50
- Spaces with VDT's.....75

Paint Shop
- Spraying, rubbing, hand art, stencil.....20-50
- Fine hand painting & finishing.....50-100

Paper Manufacturing
- Beaters, grinding.....20-50
- Finishing, cutting.....50-100
- Hand couting.....50-100
- Paper manchine reel, inspection.....100-200
- Rewinder.....100-200

Printing
- Photo engraving, etching. blocking.....20-50
- Color inspecting.....100-200
- Presses.....50-100
- Proofreading.....100-200
- Composing room.....50-100

Schools
- Reading.....20-100
- Typing.....20-100
- Demonstrations.....100-200
- Sewing.....20-100

Sheet Metal Works
- General.....100
- Tin plate inspection, galvanized, scribing.....100-200

Barber Shops
Beauty Parlors....................................50-100

Chemical Works...30

Clothing Manufacturer
Receiving, storing, shipping,
winding, measuring...............................20-50
Pattern making, trimming......................50-100
Shops, marking...................................50-200
Cutting, pressing............................100-500(a)
Sewing, inspection..........................200-500(a)

Electrical Equipment Manufacturing
Impregnating...20-50
Insulating coil winding, testing..............50-100

Food Service Facilities
Dining areas
Cashier...20-50
Cleaning...10-20
Dining..5-20
Food displays.......................................30-100
Kitchen...50-100

Foundries
Annealing furnaces................................20-50
Cleaning...20-50
Core making..50-200
Inspection
Fine..100-500
Medium..50-100
Molding..50-200
Pouring, sorting...................................50-100

Control platforms, repairs,
mixer building..30
Rolling mills...30-50
Shearing...50
Tin plate...50
Motor room, machine room..........................30
Inspection..100

Laundries
Washing..20-50
Ironing..20-100

Library
Ordinary reading, stacks.........................20-50
Book repair and binding..........................20-50
Study & notes, cataloging,
card files, check desk...........................20-100

Machine Shops
Rough bench...20-50
Medium bench, rough
grinding, buffing...................................50-100
Fine bench and work.........................200-500(a)

Materials Handling
Loading trucking....................................10-20
Picking stock classifying.........................20-50
Wrapping, packing, labeling....................20-50

Offices
Accounting..50-100
Audio-visual areas..................................20-50
Conference areas...................................20-70
Corridors, stairways.................................20(k)
Drafting...50-200
General and private offices...................50-100
Lobbies, lounges and
reception areas.......................................0-20

Stores
Circulation area stockroom.....................10-30
Merchandising, serviced.......................30-100
Merchandising, self-service.......................200

Textile Mills
Cotton picking, carding,
roving, spinning...50
Beaming & slashing..................................150
Drawing..200
Others...100

Warehousing, Storage
Inactive...5-10
Active
Rough bulky..10-20
Medium...20
Fine...20-50

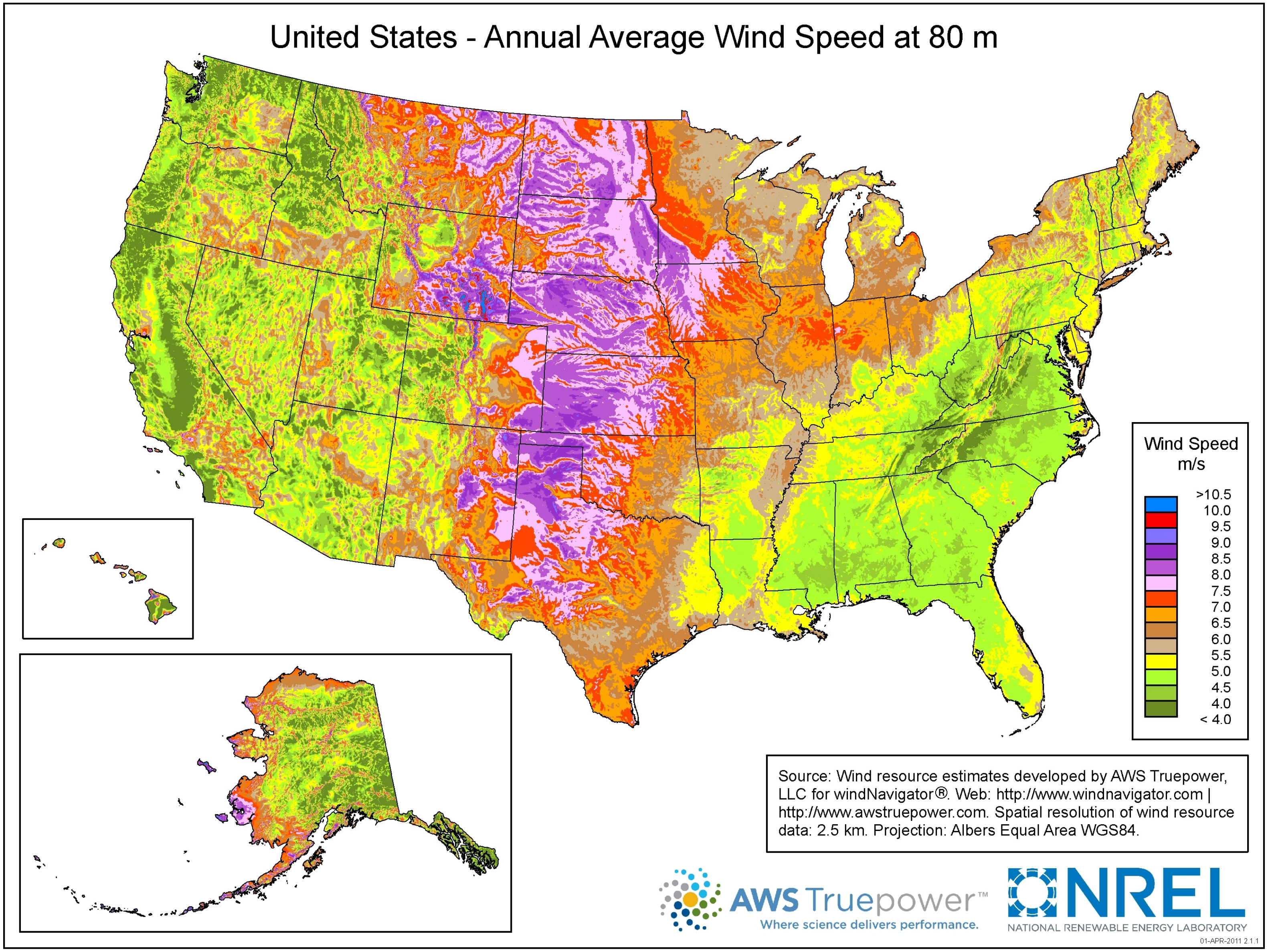
Welding
General..20-50

Woodworking
Rough sawing and bench work..............20-50
Sizing, planing, rough sanding,
medium quality machine and
bench work, gluing,
veneering, cooperage............................20-50
Fine bench and machine work,
fine sanding and finishing.....................50-100

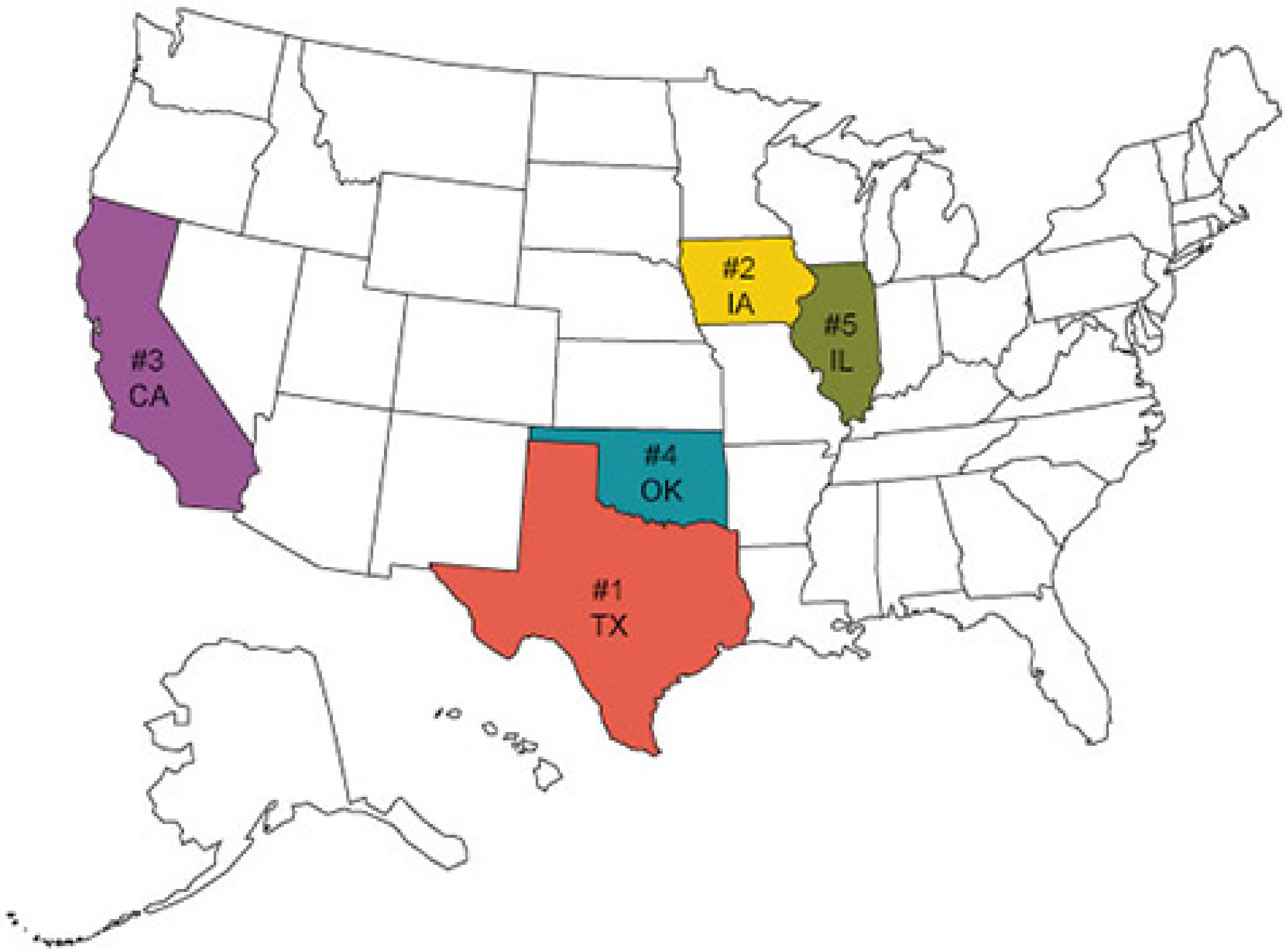
Footnotes:
(a) Obtained with a combination of general light plus specialized supplementary lighting

(k) Or not less than 1/5 the level in adjacent areas

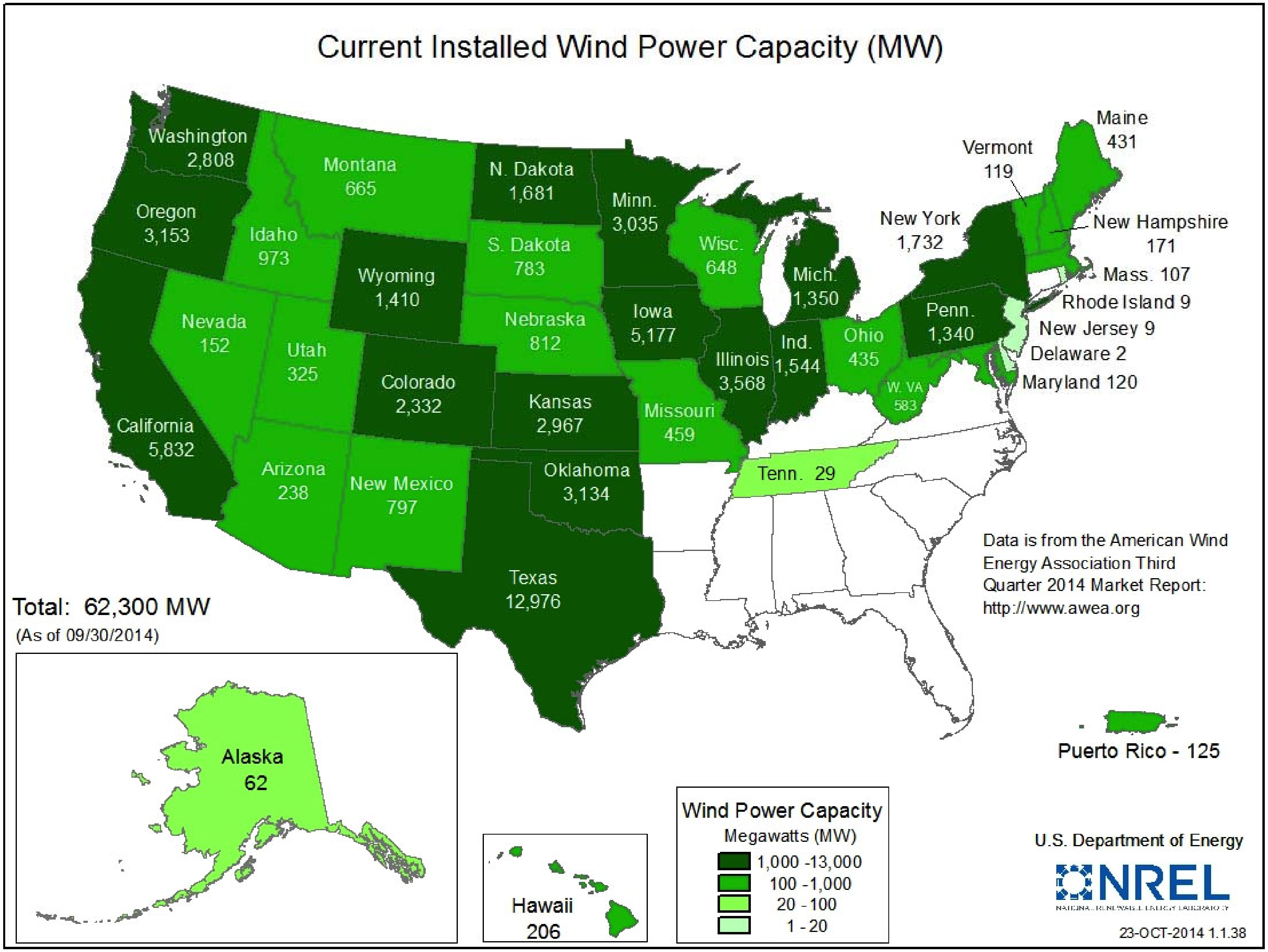
APPENDIX K: ANNUAL AVERAGE WIND SPEED MAP

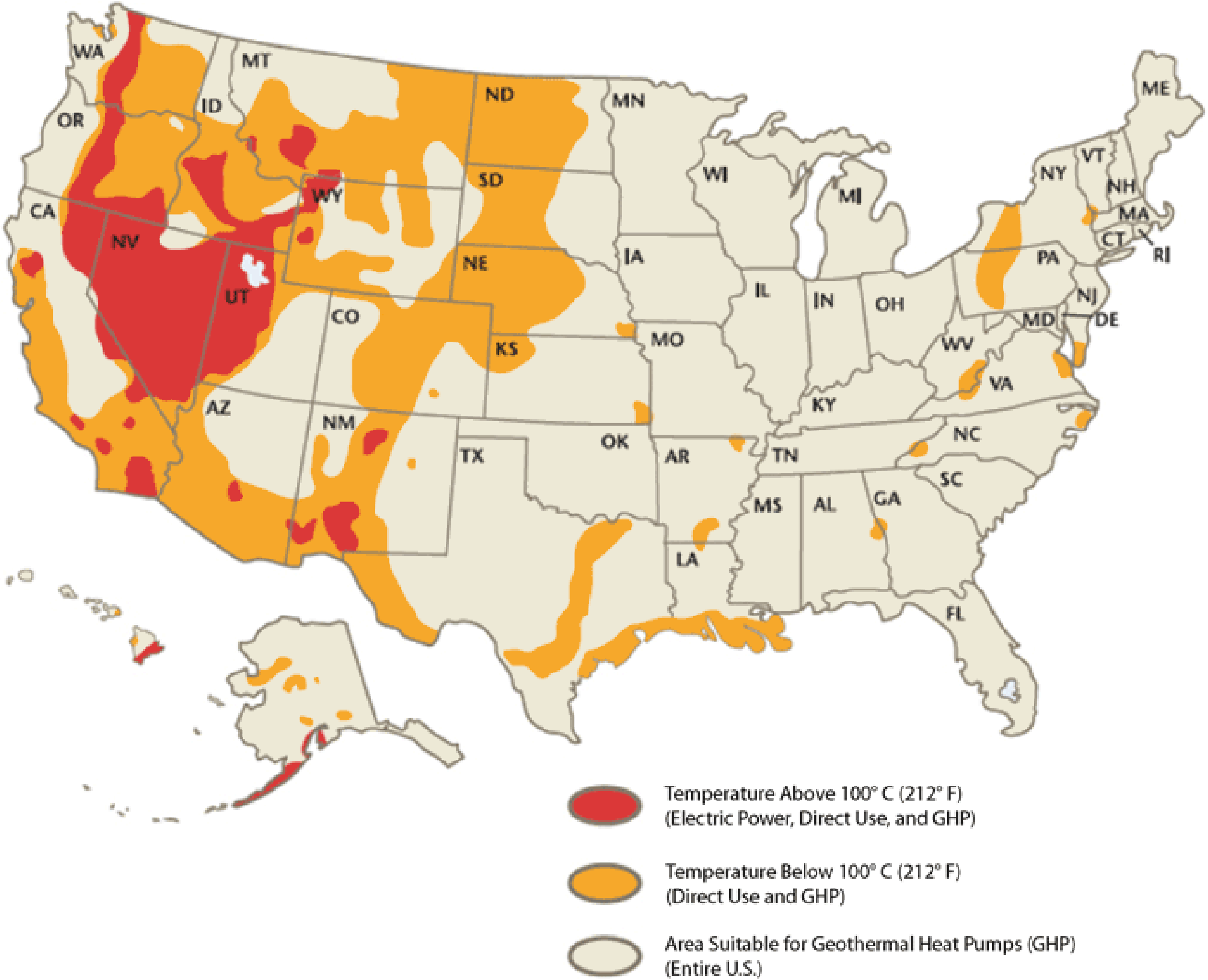


Top wind power producing states, 2013



Source: U.S. Energy Information Administration, *Electric Power Monthly*, Table 1.17.B (February 2014).


Current Installed Wind Power Capacity (MW)
Washington 2,808
Oregon 3,153
California 5,832
Nevada 152
Idaho 973
Montana 665
Wyoming 1,410
Utah 325
Arizona 238
New Mexico 797
Colorado 2,332
N. Dakota 1,681
S. Dakota 783
Nebraska 812
Kansas 2,967
Oklahoma 3,134
Texas 12,976
Minn. 3,035
Iowa 5,177
Missouri 459
Wisc. 648
Illinois 3,568
Mich. 1,350
Ind. 1,544
Ohio 435
W. VA 583
Tenn. 29
Penn. 1,340
New York 1,732
Vermont 119
Maine 431
New Hampshire 171
Mass. 107
Rhode Island 9
New Jersey 9
Delaware 2
Maryland 120
Data is from the American Wind Energy Association Third Quarter 2014 Market Report: http://www.awea.org
Total: 62,300 MW
(As of 09/30/2014)
Alaska 62
Hawaii 206
Puerto Rico - 125
Wind Power Capacity
Megawatts (MW)
1,000 -13,000
100 -1,000
20 - 100
1 - 20
U.S. Department of Energy
NREL
23-OCT-2014 1.1.38


WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MI
IN
OH
KY
TN
MS
AL
GA
FL
SC
NC
VA
WV
PA
NY
MD
DE
NJ
CT
RI
MA
VT
NH
ME
Temperature Above 100° C (212° F)
(Electric Power, Direct Use, and GHP)
Temperature Below 100° C (212° F)
(Direct Use and GHP)
Area Suitable for Geothermal Heat Pumps (GHP)
(Entire U.S.)

A:

Array: Solar panels arranged in a group to capture sun light to convert it into usable electricity.

Automatic Fire Alarm System: A system which automatically detects a fire condition and actuates fire alarm signaling devices.

Automatic Fire Extinguishing System: An approved system of devices and equipment which automatically detects a fire and discharges an approved fire-extinguishing agent onto or in the area of a fire.

B:

BTU/hr: Measurement of heating and cooling. 1 BTU is the energy required to heat 1 pound of water 1 degree.

Building: Refers to one of several categories of historic properties. Buildings refer to places that primarily shelter human activity, while structures are related to purposes other than human shelter.

C:

Central Fan System: A mechanical indirect system of heating, ventilating, or air-conditioning. Air is treated or handled by equipment that is usually located outside the rooms served at a control location and conveyed to and from the rooms via a fan and system of distributing ducts.

Centralized System: A majority of the mechanical systems (chillers, pumps, air handlers, etc.) are located in one mechanical space.

Character defining features: Aspects that are integral to a building or structure's historic and architectural significance and integrity. Character defining features are usually physical aspects such as the overall shape, design, materials, windows, craftsmanship, decorative features and defining features of the site layout or landscape context. The SHPO determines what features of the property have the status of "character defining features."

Chiller: A machine that removes heat from a heat transfer liquid using a refrigeration cycle.

Closed Loop Control: A closed loop control directly senses the controlled variable and uses that signal to adjust the controlled device.

Code: Is the legally enforceable criteria that projects must meet. In the case of DoD properties, the Unified Facility Criteria (UFC) is the applicable code document.

Coefficient of Performance (COP): The ratio of heating or cooling provided (in watts) divided by the electrical energy consumed (in watts). Better performing equipment has a higher COP.

Coil: A heat exchanger in which liquid is circulated to provide heating or cooling to the air that passes through the heat sink fins.

Constant Air Volume (CAV): Use of constant air flow volume to a zone to thermally condition the zone.

Cooling Degree Days (CDD): Number of days multiplied times the average temperature difference between the outside temperature and a desired average indoor temperature, typically 65 degrees (averaging desired day and night temperatures). CDD are specific to a location and a time period.

D:

Delta T: The difference between the desired inside temperature and the outside temperature.

Distribution: Moving air to or in a space by an outlet discharging supply air.

E:

Eligible: Refers to the status of a structure 50 years or older that has not been placed on the National Register of Historic Places (NRHP), but is deemed by the SHPO to be eligible. A building or structure that has been declared "eligible" for the NRHP is afforded the same protections as a registered building.

Energy Bible: a non-governmental website "dedicated to providing the public with up-to-date information on renewable energy." (www.Energybible.com)

Energy Efficiency Ratio (EER): The EER is similar to the Coefficient of Performance (COP), and is the ratio of output cooling (in BTU/hr) to electrical energy input (in watts).

F:

Fan Coil Unit: A fan and a heat exchanger for heating and / or cooling assembled within a common casing.

Fenestration: The arrangement, proportioning, and design of windows and doors in a building. (www.merriam-webster.com).

Forced Air HVAC Systems: Use fans, ductwork, heating, and cooling sections to temper and distribute air.

Free Standing Photovoltaic System: Electrical system which received its power from solar panels which are independent of the utility grid. System may be used in conjunction with batteries and wind turbines.

Furrout: A means of supporting a finished surfacing material away from the structural wall or framing. Used to level uneven or damaged surfaces, or to provide a space between substrates. (Gypsum Construction Handbook, 436). A furrout can be used as a means to provide significant insulating value to an exterior wall construction.

G:

Gang Mud Ring: Electrical boxes for outlets, switches and controls may be grouped together in “gangs”. The gang mud ring provides a flush edge for finishes in walls and ceilings to border around the box.

Grid-tied: Solar panels which are connected to the facility electrical system and the utility grid with excess power being fed back to the utility.

Guidelines: When the word “Guidelines” is used to refer to the Secretary of the Interior’s Standards for Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings, its use is described by the National Park Service as follows: “The Guidelines have been prepared to assist in applying the Standards to all project work; consequently, they are not meant to give case specific advice or address exceptions or rare instances.” (http://www.nps.gov/history/hps/tps/standguide/overview/using_standguide.htm). When the word “Guidelines” is used in other contexts in this document, such as in the title of this report, it does not have the authority of the National Historic Preservation Act of 1966. These “Guidelines” are suggestions that can assist project planners and managers who need to meet the Secretary of the Interior’s Standards and Guidelines while trying to reduce the energy use of historic properties.

H:

Heating Degree Days (HDD): Number of days multiplied times the average temperature difference between the outside temperature and a desired average indoor temperature, typically 65 degrees (averaging desired day and night temperatures). HDD are specific to a location and a time period.

Heat Island Effect: An effect common to urban centers in which “built up areas are hotter than nearby rural areas. The annual mean air temperature of a city with 1 million people or more can be 1.8-5.4°F. Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water supply. (from the U.S. EPA, http://www.epa.gov/heatisland/).

Heat Sink: Any environment or medium that absorbs heat. (Dictionary.com, "heat sink").

Historic resource or **historic property:** Any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register of Historic Places (National Register; NRHP).

Historic district: A significant concentration, linkage, or continuity of sites, building, structures, or objects united historically or aesthetically by plan or physical development. A single building slated for remodeling or an energy upgrade might not seem eligible by itself, but might require the SHPO's review because it is in a historic district, and it is designated as contributing to that district.

Hydronic Heating and Cooling Water Piping: HVAC systems can use this type of piping instead of ductwork to aid in distributing the heating/cooling air.

I:

Individually eligible property: A single building, structure, site, or object that meets the National Register criteria for designation. If such a property is a building or a structure, it may include interior as well as exterior features. It could also include landscaping features immediately surrounding the property.

Insulation: The resistance of heat (energy) transfer. Higher insulation (higher R-values) reduce the heating or cooling requirements of spaces.

K:

Kilowatts: A measurement of electrical energy.

M:

MBH: A unit of measurement used for heating and cooling. 1 MBH refers to one thousand BTU per hour. 12 MBH = 1 ton.

Modified Bituminous Membrane Sheet: Modified bituminous membrane sheet is a type of roofing used primarily on flat and low sloped roofs. It is made of asphalt sheets that have been modified by solvents. Often, the sheets are welded and sealed to each other with heat applied by a torch.

Mullion: A slender vertical member that forms a division between units of a window, door, or screen or is used decoratively. (www.merriam-webster.com).

Muntin: A strip separating panes of glass in a sash. (www.merriam-webster.com).

N:

Nomenclature: A system or set of terms or symbols especially in a particular science, discipline, or art. (www.merriam-webster.com).

O:

Off-grid: See Free Standing Photovoltaic System.

Open Loop Control: An open loop control does not have direct feedback from the control variable to the controller.

P:

Packaged Rooftop Unit: A complete air handler system, typically with multiple cooling and heating stages.

R:

R-Value: R-values represent the insulation value of materials. R-values are generally measured in hour x sf x degF/BTU for a given material, but can also be measured per inch of material thickness.

Refrigerant Piping: See Hydronic Heating and Cooling Water Piping definition.

S:

Scupper: An opening in the wall of a building through which water can drain from a floor or flat roof. (www.merriam-webster.com).

Site: Refers to one of several categories of historic properties. Sites are locations of significant events (prehistoric or historic in time) with historical, archaeological, or cultural value regardless of whether or not there is a standing building or structure.

Soffit: The underside of a part or member of a building, such as an overhang or staircase. (www.merriam-webster.com).

Stand Alone Photovoltaic System: See Free Standing Photovoltaic System.

Standards: When capitalized, "Standards" refers to the Secretary of the Interior's Standards for the Treatment of Historic Properties. These Standards are described in the National Park Service website as follows:

"The Standards are neither technical nor prescriptive, but are intended to promote responsible preservation practices that help protect our Nations' irreplaceable cultural resources. For example, they cannot, in and of themselves, be used to make essential decisions about which features of the historic building should be saved and which can be changed. But once a treatment is selected, the Standards provide philosophical consistency to the work." (http://www.nps.gov/history/hps/tps/standguide/overview/choose_treat.htm).

The Secretary of the Interior's Standards for the Treatment of Historic Properties have the authority of the National Historic Preservation Act of 1966, as amended.

Structure: Refers to one of several categories of historic properties. Buildings refer to places that primarily shelter human activity, while structures are related to purposes other than human shelter.

Synergistically: Refers to distinct agencies which have the capacity to act in synergism – the interaction of discrete agencies, agents, or conditions such that the total effect is greater than the sum of the individual effects. (www.merriam-webster.com).

T:

Task Lighting: Lighting which is designed to increase illumination at the level where tasks are completed, such as office desks or reading tables.

Therm: 100,000 BTUs. Typical measurement for natural gas or propane usage.

Thermal Mass: Material that is dense and weighty. Thermal mass slows heat transfer due to its depth. Concrete, brick and stone masonry, and adobe walls can act as thermal masses if they are thick enough to cause delay in heat transfer.

Ton: Measure of air conditioning output. One ton is 12,000 BTU/hr or 12 MBH.

Tracking System: For solar panels, 'track' the sun to maintain the optimal angel to the sun to provide the maximum efficiency from the solar panels.

Transom: A window above a door or other window built on and commonly hinged to a transom – a transverse piece in a structure, such as a lintel. (www.merriam-webster.com).

Trombe Wall: A passive solar system, used to heat and cool buildings, which uses the thermal mass of a masonry wall along with solar gain and glazing properties. It is a glass-fronted exterior concrete/masonry wall that absorbs solar heat for radiation into a building. (Dictionary.com, "trombe wall").

U:

U-Factor: U-factors are the inverse of R-values, and measure how well heat is conducted through an assembly. Materials with lower U-factors reduce heating and cooling losses.

Undertaking: A project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a federal agency, including those carried out by or on behalf of a federal agency; those carried out with federal financial assistance; and those requiring a federal permit, license, or approval (36 CFR § 800.16(y)).

V:

Variable Air Volume Systems (VAV): These are 'forced-air' systems, but can operate effectively at lower airflows when conditions allow the reducing of energy usage. They use a variable air flow volume to a zone to thermally condition the zone.

Variable Refrigerant Flow HVAC System (VRF):

Ventilation: An important factor in the comfort and safety of building occupants. Ventilation is fresh 'outside air' brought into the space.

APPENDIX P: ABBREVIATIONS

A:

ACHP	Advisory Council on Historic Preservation
AHU	Air Handling Unit
AIA	American Institute of Architects
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers

B:

bd	Board (as in gypsum board)
BTU	British Thermal Units (measurement of energy)
BTU/h or BTUh	British Thermal Units per hour (measurement of power)

C:

CAV	Constant Air Volume System
CDD	Cooling Degree Days
CFL	Compact Fluorescent Lamp
CFM	Cubic Feet Per Minute
CHWR	Chilled Water Return
CHWS	Chilled Water Supply
CMU	Concrete Masonry Unit
COP	Coefficient of Performance
CRM	Cultural Resource Manager

CSI	Construction Specifications Institute

D:

degF	Degrees Fahrenheit
DoD	Department of Defense
DSIRE	Database of State Incentives for Renewables and Efficiency (part of NREL)
DX	Direct Expansion (Refrigeration Cycle)

E:

EER	Energy Efficiency Ratio
EGS	Enhanced Geothermal Systems
EIA	Energy Information Administration
EIFS	Exterior Insulation and Finish Systems
EIMA	EIFS Industry Members Association
EO	Executive Order
EPA	Environmental Protection Agency
ERV	Energy Recovery Ventilator
ESTCP	Environmental Security Technology Certification Program

F:

FAS	Fire Alarm Systems
FC	Fan Coils

FEMP	Federal Energy Management Program

G:

GIS	Geographic Information System
GISS	NASA Goddard Institute for Space Studies
GPM	Gallons Per Minute (flowrate of heating/cooling water)

H:

HDD	Heating Degree Days
HID	High Intensity Discharge Lamps
hr	Hour
HVAC	Heating, Ventilation, and Air Conditioning
HWR	Hot Water Return
HWS	Hot Water Supply

I:

IBC	International Building Code
IECC	International Energy Conservation Code
IES	Illuminating Engineer Society
in	Inches
Insul	Insulation

IREC	Interstate Renewable Energy Council

K:

KVA	1,000 volt amps
kW	Kilowatts
kWh	Kilowatt Hour (measure of electricity)

L:

LCD	Liquid Crystal Display
LCA	Life Cycle Analysis (or Assessment)
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design

M:

MAU	Makeup Air Unit
MBH	One thousand BTUs/hr
MSW	Municipal Solid Waste
MW	Megawatt

N:

NASA	National Aeronautics and Space Administration
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act of 1966

NPS	National Park Service
NREL	National Renewable Energy Laboratory
NRHP	National Register of Historic Places

P:

PEX	Crosslinked polyethylene (type of piping)
PP	Polypropylene (type of piping)
PV	Photovoltaic

R:

ROI	Return on Investment
RTU	Roof Top Unit

S:

SEDS	State Energy Data System
SEER	Seasonal Energy Efficiency Ratio. SEER is higher than EER for the same equipment.
SERDP	Strategic Environmental Research and Development Program
sf	Square Feet
SHPO	State Historic Preservation Officer
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SNS	Sympathetic Nervous System
SOI	Secretary of the Interior

SOI Standards	Secretary of Interior Standards for Rehabilitation

T:

THPO	Tribal Historic Preservation Officer
TPO	Thermoplastic Polyolefin Membrane Roof

U:

UFC	Unified Facilities Criteria
UL	Underwriters Laboratories
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code
US DOE	United States Department of Energy

V:

V	Volt
VAV	Variable Air Volume System
VRF	Variable Refrigerant Flow